UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF OKLAHOMA

STATE OF OKLAHOMA, ex. rel. W.A. DREW EDMONDSON, in his capacity as ATTORNEY GENERAL OF THE STATE OF OKLAHOMA and OKLAHOMA SECRETARY OF THE ENVIRONMENT, J. D. Strong, in his the capacity as the TRUSTEE FOR NATURAL RESOURCES FOR THE STATE OF OKLAHOMA,

Plaintiffs,

v.

TYSON FOODS, INC., TYSON POULTRY, INC., TYSON CHICKEN, INC., COBB-VANTRESS, INC., AVIAGEN, INC., CAL-MAINE FOODS, INC., CAL-MAINE FARMS, INC., CARGILL, INC., CARGILL TURKEY PRODUCTION, LLC, GEORGE'S, INC., GEORGE'S FARMS, INC., PETERSON FARMS, INC., SIMMONS FOODS, INC., and WILLOW BROOK FOODS, INC.,

Defendants.

Case No. 05-CV-329-GKF-SAJ

EXPERT REPORT OF

Timothy J. Sullivan, Ph.D.
President

E&S
Environmental
Chemistry, Inc.

January 29, 2009

I. INTRODUCTION

A. Qualifications

I have a PhD in biological sciences from Oregon State University, through a multidisciplinary program that involved three areas of focus: environmental chemistry, ecology, and zoology. I have 30 years of experience in environmental effects research, mostly focused on water quality and the impacts of human activities on water quality. I have published more than 100 peer-reviewed journal articles, books, book chapters, and technical reports describing the results of this research. I co-founded and have been President of E&S Environmental Chemistry, Inc. since 1988. We conduct environmental research and consulting projects for government, industry, and stakeholder groups. I have also been President of E&S Environmental Restoration, Inc. since 1996. We conduct on-the-ground environmental restoration projects on agricultural and forestry lands, and we also market native grass seed for ecological restoration. I have taught a graduate course in Watershed Science at Rensselaer Polytechnic Institute, NY and biological science courses at Western State College, CO. Below, I highlight some of my work experience in areas particularly relevant to the Illinois River project.

I have experience studying the influence of land use on the water quality of lakes, rivers, and streams. This includes about 20 years of experience conducting watershed assessments and spatial analyses using geographic information systems (GIS) to determine relationships between human activities in the watershed and the quality of surface waters.

I have managed multiple projects that have examined the influence of human activities on nutrient and fecal bacteria concentrations in river water. Land uses have included agriculture, forestry, rural residential development, and urban development. I have extensive experience managing and writing watershed assessments. Assessment of the contribution of nutrients and bacteria to surface waters, and the effects of such contributions on water quality, are important parts of all of our watershed assessments. Each of these assessments (10 to date) has evaluated water quality of the river system and aquatic/riparian habitat, as influenced by human activities, including forestry, agriculture, urban and residential development, and water use.

I have 10 years of experience studying the effects of agriculture, especially livestock operations, on the quality of river and estuary water and the role of Best Management Practices (BMPs) in reducing water pollution. I also have 10 years of experience managing on-the-ground ecosystem restoration projects, especially focused on riparian zones, and implementation of BMPs. Much of this work has occurred in agricultural settings.

Some relevant projects have included the following:

- Responsible for synthesis and integration and report writing for watershed assessments/analyses for the Wilson, Trask, Miami, Necanicum, Umpqua Basin (four reports), Upper Sprague, and North Santiam River watersheds in Oregon.
- Principal investigator of project for U.S. Department of Energy to investigate the roles of land use and landscape in the chemistry of surface waters. Involved evaluation of disturbances in the watersheds and comparing them with the chemistry of the lakes.
- Served as project manager for a modeling project to assess aquatic and terrestrial effects of air pollutants in the eight-state southern Appalachian Mountains region for the Southern Appalachian Mountains Initiative (SAMI). Involved investigation of

bacteria (which can substantially skew an average concentration) has little or no meaning. This is largely why bacterial standards are based on calculation of a geomean (which is not heavily skewed by a single high value) of five or more samples.

2. *Concentrations of P and fecal indicator bacteria in the IRW are similar to streams and reservoirs commonly found elsewhere in Oklahoma, the region, and the nation.*

Plaintiffs' consultants allege that concentrations of P and fecal indicator bacteria are high in the waters of the IRW. Nevertheless, they do not adequately compare such measurements with data collected elsewhere. Of interest in this regard are concentrations throughout the state of Oklahoma, the ecoregions in which the IRW is located, the general region of the country in which the IRW is located, and the United States as a whole. I did compile available data, examine publications, and conduct analyses to illustrate such comparisons. Results are described below.

Spatial Patterns in Oklahoma

Failure to support water quality beneficial uses is quite common in Oklahoma. For example, the Oklahoma Water Resources Board has established an ambient monitoring network of 100 active permanent water quality monitoring stations which are evaluated annually. According to the Beneficial Use Monitoring Program (BUMP) Draft 2007 Streams Report (OWRB 2007), only 11 of those monitoring sites fully supported the primary body contact recreation beneficial use during that year. The Oklahoma Water Quality Assessment Integrated Report for 2004 (ODEQ 2004) designated 33,221 miles of rivers and streams in the state as having the beneficial use of primary body contact recreation. Of those river and stream miles, only 471 miles were determined to be fully supporting the beneficial use, and 6,546 miles were determined to be not supporting the beneficial use. The remaining miles were not assessed or were judged to have insufficient information. Thus, of the river and stream miles determined by the state of Oklahoma to be either supporting or not supporting the primary body contact recreation standard, 93% were judged to not support this beneficial use.

Figures 2-1 through 2-3 show the concentrations of total P in stream water at sampling sites throughout Oklahoma. Data are presented as the geomean of available data for all sites represented by five or more samples during the period 2000 to 2007. Three separate maps are shown, representing three different sources of data: U.S. Geological Survey, EPA STORET, and Oklahoma Water Resources Board. These maps show that stream water total P concentration is highly variable throughout the state of Oklahoma, regardless of which major data source we examine. Concentrations of total P in stream water inside the IRW are not appreciably different from streams outside the IRW. The occurrences of concentrations above the 0.037 mg/L Oklahoma water quality standard for Scenic Rivers are no more prevalent inside the IRW as compared with outside the IRW. Note that sites that have geomean total P concentration higher than the standard are shown on the maps as orange bars; green bars indicate that the geomean concentration at a given site is not above the standard.

Impacts to surface waters by fecal bacteria derived from mammals and birds is a widespread phenomenon throughout the United States, and such contamination is commonly identified using indicators of fecal inputs, especially FCB and *E. coli*. For example, there were 8,695 miles of stream listed by the state of Oklahoma as water quality impaired (303(d) list), and 70% of those stream miles were listed as a consequence of fecal bacteria contamination. Thus, fecal bacteria contamination was the most common cause of stream impairment listing in Oklahoma. Nevertheless, it is important to note that the presence of indicator bacteria does not mean that human exposure to that water will cause illness. Water pollution with waste material of human origin is the more significant public health concern because human feces is more likely to contain human-specific microbes (DuPont 2008). EPA recommended the *E. coli* standard (geometric mean of 126 cfu/100 ml) based on studies at fresh water beaches at Lake Erie, PA and Keystone Lake, OK. At both locations, there was nearby human sewage discharge (c.f., DuPont, 2008). The standard was not selected based on exposure to bacteria of non-human origin, such as for example from cattle, poultry, or other livestock. National Research Council (2004, page 173) concluded that because:

> ***animals shed bacterial indicators without some of the accompanying human pathogens, there is considerable uncertainty in extrapolating present standards to nonpoint source situations.***

Figure 2-4 shows the stream reaches in Oklahoma that were included in the 2006 draft 303(d) list for not supporting the primary body contact recreation beneficial use, based on having measured concentrations of one or more of the fecal indicator bacteria types above the designated values for classifying waters as impaired. It is my understanding that additional stream segments within the IRW have been included on the 2008 Oklahoma 303(d) list, but I do not have the spatial data that would allow those additional listed stream segments to be mapped at the time of preparation of this report. Oklahoma stream reaches that are listed for primary body contact recreation (bacteria) are shown in Figure 2-4, including the basis for listing: FCB, *E. coli*, and/or enterococcus. Such listings for fecal indicator bacteria are widely distributed throughout the state, including portions of the state that do, and those that do not, contain extensive poultry operations.

Figure 2-5 shows the distribution of poultry farming, by county, from the agricultural census and information provided by Dr. Billy Clay (pers. comm. 2008). The poultry industry is primarily confined to eastern Oklahoma, whereas 303(d) listings for bacteria and the occurrence of concentrations of FCB, *E. coli*, enterococcus, and total P above surface water standards are widespread throughout the state. There is no obvious spatial link between counties in Oklahoma that have large concentrations of poultry and locations of streams shown to have concentrations of total P or fecal indicator bacteria above water quality standards. Concentrations of these constituents above water quality standards occur commonly statewide irrespective of the spatial distribution of poultry farming activities.

The concentrations of fecal indicator bacteria in the IRW are high enough to result in 303(d) listings at some locations, but these concentrations are not unusually high, compared with values elsewhere. Again, using the state of Oklahoma as the example, concentrations above standards of all three of the bacterial indicators addressed in the state's request for a preliminary injunction are found to be well distributed throughout Oklahoma (Figures 2-4 through 2-17). Concentrations within the IRW are not higher than are commonly found elsewhere throughout the state. This pattern holds for enterococcus (Figures 2-6 and 2-7; note that enterococcus data are not available from USGS], FCB (Figures 2-8 through 2-10), and *E. coli* (Figures 2-11 through 2-13). The spatial patterns of fecal indicator bacteria concentrations in Oklahoma are not consistent with the proposition that poultry litter is an important source of these fecal bacteria indicators. Rather, concentrations of these indicators above standards appear to be common throughout Oklahoma, in areas where poultry operations are numerous and in areas where poultry operations are scarce (Figure 2-5).

Furthermore, there are many locations throughout Oklahoma where fecal indicator bacteria concentrations are substantially higher than they are in the IRW. The fact that portions of the Illinois River and its tributaries are listed as water quality impaired as a consequence of fecal indicator bacteria concentrations is not a cause for alarm. The issue is well known and is nationwide in scope.

Data presented for individual data sources (e.g., USGS, OWRB, STORET) in many of the preceding figures are combined into four maps, one for TP and one for each of the fecal indicator bacteria variables. These data are shown in Figures 2-14 through 2-17. The spatial patterns in the data are very clear, indicating that neither the concentration of P nor the concentration of any of the three fecal bacteria indicators is high in the IRW, compared with elsewhere in Oklahoma. Furthermore, the few instances of relatively high concentrations within the IRW occur adjacent to, or shortly downstream from, municipal waste water treatment facilities.

Concentrations of enterococcus above the Primary Body Contact Recreation standards are ubiquitous within the IRW. Similarly, enterococcus concentrations are above the Primary Body Contact Recreation standard at 90% (OWRB data) to 96% (STORET data) of the locations within Oklahoma where sufficient data are available to calculate a geomean of five samples (Figures 2-6 and 2-7). This suggests that either poultry litter is not the principal source of enterococcus to stream water or that poultry litter application is a common occurrence statewide. The spatial distribution of poultry operations within Oklahoma from agricultural census data (Figure 2-5) shows that poultry farming is confined primarily to eastern Oklahoma. Thus, consideration of the spatial patterns in enterococcus concentrations and poultry farming suggests that sources of enterococcus other than poultry are commonly responsible for the frequent occurrence of concentrations above the standards.

As illustrated in the series of maps described above, any allegation that TP or fecal bacteria indicator concentrations in the IRW are unusually high compared to other water bodies in Oklahoma, thereby representing an immediate and unusual health threat, is not borne out by the available data.

Stevenson (2008, page 17) reported that the median concentrations of total P in IRW streams were 0.076 mg/L in summer 2006, 0.057 mg/L in spring 2007, and 0.067 mg/L in summer 2007. The median for streams sampled by Plaintiffs' consultants for this case and reported in Dr. Olsen's database, under all flow conditions, was similar, 0.062 mg/L. Dr Stevenson (2008, page 17) concluded that these concentrations were:

> ***…relatively high in the IRW compared to many other regions***

But he did not discuss results from other regions and provided no basis or context for this statement. I have examined total P data from several large surveys and assessments, and found that concentrations of total P in the IRW are not unusual compared with data from many other locations. These results are summarized below.

Regional and National Patterns

EPA's 2000 National Water Quality Inventory Report (U.S. EPA, 2002) found that 39% of assessed stream miles and 45% of assessed lake area in the United States were impaired and did not fully achieve the water quality standards set for them. The leading sources of impairment reported by the states in 2000 were agricultural activities, hydrologic modifications (such as channelization, dredging and flow regulation), municipal sources, and urban runoff/storm sewers. Of the 88,679 miles of stream assessed for swimming use support, 28% of the assessed stream length was impaired by fair or poor water quality conditions. Litke (1999), in a review of P control measures and their effects on water quality in the United States for the USGS, stated that downward trends in P concentrations have been identified in many streams since 1970, but that:

> ***median total phosphorus concentrations still exceed the recommended limit of 0.1 milligram per liter across much of the Nation.***

They presented data that they summarized for the period 1990 to 1995 from EPA's STORET database, indicating that 32% of the hydrologic units in the conterminous United States had more than half of their measured values of TP exceeding the recommended value of 0.1 mg/L (which is 2.7 times the Oklahoma standard applicable to portions of the IRW, and is higher than the median values quoted above for the IRW [based on data summaries by Dr. Stevenson and Dr. Olsen]). Thus, contribution to surface waters of nutrients and fecal indicator bacteria is a national issue, and it has many causes. The IRW does not seem to me to be unusual in this regard.

I examined several large regional or national databases to evaluate whether concentrations in the IRW of TP or fecal indicator bacteria are unusual. Results of that inquiry are summarized below. There are certainly examples of lakes and streams in the region and in the nation that have values of these parameters that are lower than have been observed in streams and in Lake Tenkiller in the IRW. Nevertheless, as is shown by the data summarized below, concentrations of TP and fecal indicator bacteria equal to or higher than those measured in the IRW are commonplace.

Lakes

Graham et al. (2004) reported nutrient concentrations for 219 lakes in Missouri, Iowa, northeastern Kansas, and southern Minnesota. Median TP concentrations, by region, were reported as:

Ozark Highlands, 0.012 mg/L

Osage Plains, 0.045 mg/L

Dissected Till Plains, 0.079 mg/L

Western Lake Section, 0.141 mg/L

Based on the recent data summarized by Cooke and Welch (2008), the lacustrine (lake-like) portion of Lake Tenkiller for the period 2005 to 2007 has TP about equal to the median for the Ozarks Highlands and substantially below the medians for any of the other regions investigated by Graham et al. (2004).

Jones et al. (2004) reported water quality data for 135 reservoirs in Missouri, collected during the period 1978 to 2002, representing the range of reservoir resources within the state. Samples were collected near the respective dams, in the lacustrine portions of the reservoirs. The median total P concentration was 0.039 mg/L; 25% of the reservoirs had total P concentration higher than 0.058 mg/L. These data for Missouri reservoirs can be contrasted with data from Lake Tenkiller, as summarized by Cooke and Welch for their sample site near the dam (LK-01). The average TP data for site LK-01 reported by Cooke and Welch (2008, their Figure 7) was as high as 0.027 mg/L in 1974, but has decreased markedly in recent years, with values of 0.010, 0.012, and 0.011 mg/L during the most recent three years that were sampled by Plaintiffs' consultants for this case. Thus, the average TP at the dam location in Lake Tenkiller in recent years is less than one-third of the median value for representative reservoirs in the state of Missouri; nearly 75% of the reservoirs sampled in Missouri by Jones et al. (2004) have TP that is about double or more the concentration found in Lake Tenkiller.

Haraughty (1999, page 89), in the Comprehensive Basin Management Plan concluded that:

> ***Lake Tenkiller is still in fairly good shape.***

Based on analyses presented by Drs. Horne (2009) and Connolly (2009), Haraughty's (1999) conclusion appears to still apply to the lacustrine portion of the lake.

Streams

The U.S. EPA's Wadeable Streams Assessment (WSA) surveyed 1,392 (generally first through fifth order) streams throughout the United States (U.S. EPA, 2006). Sampling sites were chosen using a probability-based sampling design, such that results could be used to represent the population of streams within the sample frame, rather than just those selected for sampling. Water samples were collected during summer in the period 2000 to 2004. Although the study was not designed to make population estimates for individual states, there were 57 stream sites surveyed in Oklahoma and Arkansas. The median concentration of total P in streams that were sampled in these two states was 0.047 mg/L and the 75th percentile was 0.147 mg/L. At the national level, the median total P concentration was 0.028 mg/L and the 75th percentile was 0.077 mg/L. Thus, for both the two states (Oklahoma and Arkansas) and for the United States as a whole, the median concentrations of TP reported by Stevenson (2008,) for IRW streams were roughly between the median and 75th percentiles reported by EPA in the Wadeable Streams Assessment. That means that somewhere between one-fourth and one-half of the streams in the United States, and of the streams sampled by the WSA in Oklahoma and Arkansas, contained higher total P concentrations than were reported by Stevenson (2008) for the IRW. In general, streams within the Southern Appalachian ecoregion (median TP equal to 0.015 mg/L), and the Ozark and Ouachita segment of the Southern Appalachian Mountain ecoregion (median TP equal to 0.011 mg/L), had lower concentrations of P than streams throughout Oklahoma and Arkansas. This pattern is likely due at least in part to differences in the amounts of forested and developed lands. For example, our GIS analyses indicate that the 34 watersheds sampled by EPA in the WSA within the Ozark and Ouachita Mountains portion of the Southern Appalachian Mountain Ecoregion are 72% forested (compared with 43% in the IRW). Only 0.6% of the land within the Ozark/Ouachita watersheds sampled by EPA is developed-urban land (compared to 3.1% [five times higher] in the IRW). Thus, the streams sampled by EPA in the Ozark/Ouachita region appear to be less impacted by human activities that would be expected to contribute P to streams.

The median TP concentration of 250 U.S. Geological Survey (USGS) stream monitoring stations throughout the United States reported by Alexander and Smith (2006) was 0.12 mg/L. One-fourth of the sites had TP concentration above 0.25 mg/L and 10% were above 0.46 mg/L (Alexander and Smith 2006).

The USGS, in cooperation with the Oklahoma Water Resources Board (Haggard et al. 2003a) reported nutrient concentrations at 563 stream sites in Oklahoma and 4 sites in Arkansas to facilitate development of nutrient criteria for Oklahoma. The median and 75th percentile total P concentrations for larger streams (stream orders 4 and above) were 0.106 and 0.178 mg/L, respectively. For smaller streams (stream order 1 through 3), the median value ranged from 0.026 to 0.060 mg/L, depending on stream slope (steep streams had lower total P), and the 75th percentile values ranged from 0.05 (steep streams) to 0.110 mg/L (low gradient streams).

I analyzed the total P data in Dr. Olsen's Illinois Master Database under what Dr. Olsen classified as base flow and under all flow conditions. His base flow median and 75th percentile total P concentrations (1,071 samples) were 0.055 and 0.121 mg/L, respectively. Corresponding values under all flow conditions (1,527 samples) were 0.062 and 0.142 mg/L, respectively. These values are similar to results obtained in the other surveys discussed above.

Thus, we can put into context the median total P concentrations in IRW streams reported by Plaintiffs' consultant, Dr. Stevenson (2008) that ranged from 0.057 to 0.076 mg/L depending on the year and season, and the TP concentration at all sampling stations, as represented in Dr. Olsen's stream database for this case (median TP equal to 0.062 mg/L). While these concentrations are indeed above the 0.037 mg/L standard for designated Scenic Rivers in the IRW, they are not unusual in comparison with values reported elsewhere by the U.S. EPA and USGS. The IRW streams sampled by Plaintiffs' consultants in this case were not unusual with respect to their total P concentrations, compared with streams elsewhere in Oklahoma, the surrounding region, or the nation.

The median fecal coliform bacteria concentration for the 250 USGS stream monitoring stations was 329 cfu/100 ml. Twenty-five percent of the sites had FCB above 950 cfu/100 ml and 10% were above 2,345 cfu/100 ml (Alexander and Smith 2006). In comparison, based on Dr. Olsen's database, the median FCB concentration for streams in the IRW was 130 cfu/100 ml. Twenty-five percent of the IRW stream samples had FCB higher than 810 cfu/100 ml and 10% of the samples had FCB higher than 4,600 cfu/100 ml. Furthermore, the median watershed in the USGS study reported by Alexander and Smith (2006) may have been less impacted by human activities than is the IRW. For example, the median population density was only 14 people per square kilometer, compared with 70 people per square kilometer in the IRW. Despite the lower density of people in the median USGS watershed, it nevertheless had higher FCB concentration than the median IRW stream.

Whereas I do not necessarily accept Plaintiffs' classification of the Illinois River as eutrophic (see Connolly 2008) , many streams around the United States are considered to be eutrophic. For example, Alexander and Smith (2006) reported statistics for the 250 nationally representative riverine monitoring stations surveyed by USGS throughout the United States. About half of all sites nationwide, and about 60% of all sites situated in predominantly agricultural or urban watersheds, were classified as eutrophic in 1994 on the basis of measured TP concentrations. Alexander and Smith (2006) estimated water quality parameters standardized for stream flow and seasonal variability. Each of the stations had at least 70 records of TP; data were collected between 1973 and 1994 at sites that generally had watershed areas larger than about 1,000 km^2. They found that the median concentration of TP was 0.12 mg/L Thus, for both TP and fecal coliform bacteria, the median concentration in the IRW, based on Dr. Olsen's data collected under all flow conditions, were above some water quality standards, but nevertheless were about half as high as the median values reported by USGS for the 250 nationally representative riverine monitoring stations.

Based on results of analyses summarized above, compared with streams and reservoirs sampled in many studies throughout Oklahoma, the region of the IRW, and the United States as a whole, in a number of large surveys, neither the concentrations of TP nor fecal coliform bacteria in the IRW are unusual.

3. *Water quality data in the IRW reflect a variety of sources associated with a mix of land uses.*

The land area of the Illinois River watershed is a complex patchwork of urban, rural residential, agricultural, and forest land uses (Figure 3-1), with a variety of potential P and fecal indicator bacteria sources to stream water. Land application of poultry litter is only one among many potential sources. The most important sources of P to stream water are probably waste water treatment plant effluent, livestock, septic systems, erosion, and runoff from urban and other developed areas. The most important sources of fecal indicator bacteria are probably livestock, septic systems, urban runoff, accidental sewage discharge and other sewage bypasses, river recreationists, and wildlife. All of these sources contribute P and/or fecal indicator bacteria to stream water, dependent upon location, rainfall, flow conditions, human and animal populations, and variations in land use. Most of these sources were ignored or unreasonably dismissed as unimportant by the Plaintiffs' consultants in this case.

Because the land uses within the watershed are so patchy (see Figure 3-1) and because so much of the urban land use (a major source area of both P and fecal indicator bacteria to streams) is located in the headwater regions of the watershed, it may be impossible to discriminate precisely among the various nonpoint P and bacteria sources based on observed geographic patterns in P or bacterial concentration. Certainly the Plaintiffs' consultants did not design and implement a sampling program that discriminated among the various potentially important sources of NPS pollutants.

Headwaters are important in this assessment because stream flows in headwater areas are lower than further down the stream system, and therefore inputs of P and bacteria have larger influence on concentrations in stream water in the smaller headwater streams. Furthermore, contamination of streams with waste water treatment plant effluent and urban runoff in the headwater areas makes it difficult to evaluate the importance of multiple potential nonpoint sources of P and/or fecal indicator bacteria in agricultural and rural residential lands further downstream. Thus, streams in this watershed have concentrations of P and fecal indicator bacteria above water quality standards in the upper reaches of many of these stream systems, well above the mainstem Illinois River. The relative importance of each source is not known. These potential sources of P and bacteria cannot be ignored in any serious attempt to evaluate the possible causes of concentrations above standards at some locations in the IRW. There is no justification for singling out the poultry industry as the cause of P or fecal indicator bacteria above water quality standards in this watershed, especially given the large populations of people (on both sewered and septic waste water treatment) and cattle in the IRW. In addition, because of differences in the timing of improved land and facilities management, WWTP construction projects, and continued growth in the IRW, spatial patterns may be further obscured.

under all flow conditions, were above some water quality standards, but nevertheless were about half as high as the median values reported by USGS for the 250 nationally representative riverine monitoring stations.

Based on results of analyses summarized above, compared with streams and reservoirs sampled in many studies throughout Oklahoma, the region of the IRW, and the United States as a whole, in a number of large surveys, neither the concentrations of TP nor fecal coliform bacteria in the IRW are unusual.

3. Water quality data in the IRW reflect a variety of sources associated with a mix of land uses.

The land area of the Illinois River watershed is a complex patchwork of urban, rural residential, agricultural, and forest land uses (Figure 3-1), with a variety of potential P and fecal indicator bacteria sources to stream water. Land application of poultry litter is only one among many potential sources. The most important sources of P to stream water are probably waste water treatment plant effluent, livestock, septic systems, erosion, and runoff from urban and other developed areas. The most important sources of fecal indicator bacteria are probably livestock, septic systems, urban runoff, accidental sewage discharge and other sewage bypasses, river recreationists, and wildlife. All of these sources contribute P and/or fecal indicator bacteria to stream water, dependent upon location, rainfall, flow conditions, human and animal populations, and variations in land use. Most of these sources were ignored or unreasonably dismissed as unimportant by the Plaintiffs' consultants in this case.

Because the land uses within the watershed are so patchy (see Figure 3-1) and because so much of the urban land use (a major source area of both P and fecal indicator bacteria to streams) is located in the headwater regions of the watershed, it may be impossible to discriminate precisely among the various nonpoint P and bacteria sources based on observed geographic patterns in P or bacterial concentration. Certainly the Plaintiffs' consultants did not design and implement a sampling program that discriminated among the various potentially important sources of NPS pollutants.

Headwaters are important in this assessment because stream flows in headwater areas are lower than further down the stream system, and therefore inputs of P and bacteria have larger influence on concentrations in stream water in the smaller headwater streams. Furthermore, contamination of streams with waste water treatment plant effluent and urban runoff in the headwater areas makes it difficult to evaluate the importance of multiple potential nonpoint sources of P and/or fecal indicator bacteria in agricultural and rural residential lands further downstream. Thus, streams in this watershed have concentrations of P and fecal indicator bacteria above water quality standards in the upper reaches of many of these stream systems, well above the mainstem Illinois River. The relative importance of each source is not known. These potential sources of P and bacteria cannot be ignored in any serious attempt to evaluate the possible causes of concentrations above standards at some locations in the IRW. There is no justification for singling out the poultry industry as the cause of P or fecal indicator bacteria above water quality standards in this watershed, especially given the large populations of people (on both sewered and septic waste water treatment) and cattle in the IRW. In addition, because of differences in the timing of improved land and facilities management, WWTP construction projects, and continued growth in the IRW, spatial patterns may be further obscured.

It is well known that the land uses that are common in the IRW are often associated with contributions of nutrients such as P and fecal indicator bacteria to streams. It is also well known that it is very difficult to quantify the relative contributions from the various source types. EPA (2002, page 14) stated the following:

> ***Detecting and ranking sources of pollutants*** *(to streams)* ***can require monitoring pollutant movement from numerous potential sources, such as failing septic systems, agricultural fields, urban runoff, municipal sewage treatment plants, and local waterfowl populations. Often, states are not able to determine the particular source responsible for impairment.***

In the IRW, Plaintiffs have not conducted the monitoring identified by EPA (2002) as required to determine the particular source(s) responsible for impairment of the streams in the watershed with respect to existing water quality standards for total P and fecal indicator bacteria. However, Plaintiffs' water quality data do allow a general assessment of source areas of P and fecal indicator bacteria; concentrations of these constituents tend to be highest downstream from urban areas and WWTP facilities (see discussion in Section III.5).

Land use in the IRW includes a large amount of agricultural land, most of which is used for pasture and hay production. Urban lands also occur, and are mainly found in the upper reaches of the watershed, in the headwater areas of the Illinois River and several of its tributary streams. It is well known that watersheds having agricultural and urban land use are more likely to receive inputs of nutrients to streams and to have their drainage waters classified as eutrophic than are watersheds having forested land use (Alexander and Smith 2006).

4. *There are large numbers of people and their animals in the IRW, and Plaintiffs' consultants did not fully consider their importance as potential sources of nutrients and fecal indicator bacteria to stream waters within the watershed. Plaintiffs' consultants also did not fully consider the importance of the rapid increase in the human population that has occurred within the IRW in recent decades.*

<u>Current and Recent Population Estimates</u>

Plaintiffs' consultants largely ignored the substantial current human and cattle populations in the IRW and the extent to which the human population has been increasing in recent years, with concomitant increased potential for NPS contributions to streams.

Based on the U.S. Census, there were about 237,000 people in the IRW in the year 2000, of which approximately 160,500 lived in sewered communities, and 76,500 lived in rural areas, presumably on septic systems (Table 4-1). Such a large number of people would be expected to contribute NPS pollutants to stream waters within the watershed regardless of whether or not poultry litter had been land-applied. Pollutant sources would be expected to include bacteria and nutrients contributed via human waste (for example, from waste water treatment plant effluent, septic system drainage, leaking sewer pipes, accidental bypasses of raw sewage, land application of biosolids) and via pet waste. In addition, P can be contributed from soaps and other household products, lawn and garden fertilizer, and urban runoff from impervious surfaces (roofs, roads, sidewalks, parking lots, etc); such runoff would include nutrients and bacteria from fertilizers and animals such as birds, deer, and other wildlife, as well as pets. Roads (especially dirt roads), culverts, and stream banks from which soil-holding trees and other plants have been removed are well-known sources of erosion. Erosion includes the movement (via water, gravity, and/or wind) of soil from the land surface to a stream. It preferentially involves movement of the smaller soil particles (especially clay size particles), and erosion can carry a substantial amount of P adsorbed to soil particles.

I estimate, using American Veterinary Medicine Association estimates for 2001 of 1.7 dogs and 2.2 cats per household in the United States (http://www.avma.org/reference/marketstats/ownership.asp) together with the U.S. Census estimate of 2.67 people per household (http://www.petpopulation.org/faq.html) and the human population estimates given in Table 4-2, that there are over 189,000 dogs and 244,000 cats in the IRW. This assumes that these national estimates are applicable to the IRW, so there is some uncertainty in these estimates. Regardless, it is clear that there are large numbers of dogs and cats in the watershed. It is also obvious that these pets are especially numerous in the upper reaches of the watershed where most of the people live. Pet waste constitutes an important potential source of fecal indicator bacteria and P to urban runoff.

It is noteworthy that developed areas, which include most of the people and therefore many of the pets that reside within the watershed, also contain relatively high percentages of impervious land, from which contaminants from pets, fertilizer application, erosion, and other sources can move rapidly and efficiently to streams. This pollutant transport pathway is accentuated by storm drains, gutters, and roadside ditches that are constructed in urban areas in order to facilitate efficient movement of water into streams during rainstorms. Such water routing infrastructure is an important tool for reducing flooding in urban areas. However, it also provides an efficient conduit for transporting contaminants from the urban landscape to streams. Waste from urban wildlife, including deer, rodents, and birds, as well as cats and dogs, can further add to the flux of contaminants to streams in the urban areas.

Defendants' expert, Dr. Clay (2008), estimated that there are approximately 199,000 cattle, 166,000 swine, 8,000 horses, and 2,000 sheep present in the watershed. Cattle, in particular, have access to streams and streamside (riparian) areas throughout the watershed. Cattle tend to spend a disproportionate amount of their time in and adjacent to streams because such areas provide a source of water, often a source of shade, and an opportunity for cooling during summer months (Clay 2008).

Plaintiffs' consultants contend that cattle do not contribute P to the IRW because they merely recycle the P that is already present in the forage that they consume. This contention reflects a complete misunderstanding of NPS pollutant transport processes. As discussed in Section III.17 of this report, the mere presence of P within the watershed reveals nothing about the propensity of that P to move into a stream; one must also consider the transport opportunities and pathways. Similarly, one cannot ignore the importance of cattle-mediated transport of P from the location of forage ingestion in a pasture directly to the stream or to the riparian area adjacent to the stream. This is critically important because P is typically not readily transported from pasture to stream. Rainfall on much of the surface of a pasture tends to infiltrate into the soil where the P can become adsorbed, rather than running off the surface as overland flow (see discussion in Section III.7 of this report). In contrast, cattle that have free access to streams can directly deposit their feces (with its P and bacteria content) into a stream or to the adjacent riparian land that may be hydrologically active, from which transport to the stream can readily occur during a rainstorm. Thus, the actions of cattle, consuming forage throughout the pasture and then preferentially depositing their feces in or near the stream, constitute an important source contributing P and fecal indicator bacteria to streams in the IRW that was largely ignored by Plaintiffs' consultants.

It is largely because cattle can represent a major NPS pollutant transport mechanism in pasture settings that agricultural best management practices (BMPs) commonly entail construction of fences (with associated off-stream watering systems) to keep cattle out of riparian zones and streams. Intended benefits of riparian fencing include reduced contamination of stream water with livestock feces and its associated nutrient and bacteria content, reduced trampling of riparian vegetation, and reduced stream bank and riparian erosion. Riparian fencing resource protection actions occur nationwide, in many cases funded by the federal government.

It is well-recognized that cattle pose an important source of NPS pollution to streams. In fact, Total Maximum Daily Load (TMDL) analyses in watersheds throughout much of Oklahoma typically conclude that cattle constitute the principal source of fecal indicator bacteria to streams (See discussion of this issue in Section III.6 of this report). Nevertheless, Plaintiffs' consultants largely ignored or dismissed the importance of cattle in the IRW, despite the large numbers of cattle present and the wide prevalence of their access to streams within the watershed.

Plaintiffs' consultants also failed to fully address the fact that feces from an estimated 170,000 swine that live in the IRW are commonly land applied. Waste water treatment biosolids have also been land applied (Jarman 2008). Plaintiffs' consultants did not appropriately address these potential sources of contaminants to stream water, but instead focus on poultry litter, nearly to the exclusion of other known and suspected sources of P and fecal indicator bacteria.

Change in Populations Over Time

The human population in the IRW has been increasing dramatically for the past several decades. Between 1990 and 2007, it increased by about 77% (Table 4-2). In fact, northwest Arkansas has been one of the fastest growing metropolitan areas in the United States in recent years. The total human population in the watershed has increased from about 168,000 people in 1990 to about 297,000 people in 2007 (Table 4-2).The estimated total human population in the IRW increased by over 40% just within the decade of the 1990s. Much of this increase has occurred in the headwater areas of the IRW in the northeastern portions of the watershed. Changes over just a seven year period of time are mapped in Figure 4-1. Human population increases have been especially pronounced in the upper (easternmost) part of the watershed.

Along with the large increase in human population has been a large amount of construction: of housing, shopping centers, and other human infrastructure. Construction activities and urban development are especially widespread throughout the headwater portion of the watershed. For example, Grip (2008) mapped, from examination of aerial photographs and existing maps, new land development in a study area between Rogers and Fayetteville, within the IRW. The study area comprised 152 square miles. Mr. Grip obtained aerial photographs that covered the study area, corresponding to four time periods: 1976-1982, 1994-1995, 2001, and 2006. Developed areas that involved residential and commercial development were identified and mapped, excluding any development that was focused on golf courses, parkland, forestry, crops or pasture. During the initial time period examined (1976-1982), 12.6% of the study area was classified as developed. By 1994-1995, this increased to 22.4%; by 2001, it increased to 29.4%. The cumulative development by 2006 had increased to 39.3%, more than three times the amount of developed land in the earliest period examined (approximately 24 to 30 years previously).

With construction and urban development, there is a substantial increase in the amount of impervious land surface (pavement, roofs, parking lots, compacted soils, etc). Runoff during rainstorms from these impervious areas is largely not directed down through soils (which could remove bacteria from the drainage water), but rather flows overland and through storm drains, providing direct conduits for bacterial and nutrient transport from the ground surface to stream water. Thus, eroded sediment and also bacteria and P deposited on the ground surface by pets, hobby farm livestock, or wild mammals and birds can be efficiently transported from such areas to streams. For this reason, urban areas and developed areas commonly constitute important sources of NPS pollutants to streams. Plaintiffs' consultants have ignored the rapid increase in the human population within the watershed, along with the concomitant large increase in such potential sources of stream pollution.

5. *Effluent and drainage water from urban areas in general, and municipal waste water treatment plants in particular, are major sources of P to surface waters in the IRW.*

Urbanization is well-known as a major source of NPS pollution in the United States (Dillon and Kirchner 1975, Novotny 1995). Nevertheless, it was not fully considered by Plaintiffs' consultants in this case. Other than providing a limited and incomplete evaluation of waste water treatment effluent sources to streams and deleting watersheds having urban land use from some analyses, aspects of urban contribution of NPS pollution were generally not investigated by Plaintiffs' consultants.

My analyses show that spatial patterns in measured total P concentrations in stream waters of the IRW indicate an association with urban land use, and especially with the location of WWTP effluent discharge. Analyses conducted and reported by Defendants' expert Dr. Connolly (2008) further support this conclusion. As described below, highest values of stream total P concentration tend to be located downstream of urban land use and especially downstream of WWTP effluent sources to the streams. Plaintiffs' own data show that the sites that exhibit the highest concentration of total P, expressed as the geomean of five or more samples at a given location, are immediately downstream of the locations of WWTPs, sewage lagoons and/or urban areas.

Plaintiffs' consultants ignored or failed to recognize that stream water P concentrations in the IRW tend to be highest immediately downstream of urban pollution sources. Their analyses were directed towards portions of the watershed assumed to receive land application of poultry litter, and they failed to fully consider the presence of other potential sources of the same constituents that they claimed were contributed to streams from poultry litter application.

As an example, Plaintiffs' consultants collected paired stream samples above and below three waste water treatment plant effluent discharge locations. The resulting total P data are depicted in Figure 5-1, showing that the concentrations of total P in the streams were generally below the 0.037 mg/L standard at the locations above the WWTPs, but substantially higher immediately downstream from the WWTPs. Plaintiffs' consultants did not report such observations in their various reports for this case.

Similarly, an analysis of data collected by Plaintiffs' consultants at variable distances downstream from several WWTP locations (shown in Figure 5-2) illustrate that concentrations of total P in stream water tend to be highest immediately downstream of the location of the WWTP effluent discharge point, and subsequently decrease further downstream (Figure 5-3). Similar results were found by Haggard et al. (2001) in an investigation of the effects of the Columbia Hollow WWTP on Spavinaw Creek, Arkansas; they found a marked increase (about 8 to 25 times higher) in soluble reactive P in the stream immediately below the point of WWTP discharge compared with above the discharge, with a gradual decline in the P concentration in the downstream direction below the WWTP. The concentration of P in stream water decreases gradually in a downstream direction from the WWTPs in part because P settles to the stream sediment. The P that accumulates in the sediment can later be remobilized by high stream flows or in response to changing equilibrium conditions between the stream water and the sediment. Haggard et al. (2001) further concluded that the nutrient retention capacity of the stream was greatly reduced as a consequence of the point source. They concluded that:

> ***PS [*point source*] inputs diminish the ability of the stream to withstand other anthropogenic nutrient inputs***

All of these spatial patterns observed in the Plaintiffs' database illustrate the strong association between WWTP effluent (and also urban land use in general) and the occurrence of relatively high concentrations of total P in streams in the IRW. These patterns suggest that the largest sources of P to streams in the IRW are likely associated with urban development. This finding is not new or surprising. As discussed more fully below, urban development is commonly associated with both point and nonpoint source pollution of streams. There is a great deal of urban development in the IRW, and much of that development is recent. Nevertheless, Plaintiffs' consultants generally chose to focus on a presumed linkage with land application of poultry litter, almost to the exclusion of other sources, including the urban sources that their own data implicate as critically important in this watershed.

The finding that stream P concentrations in the IRW are strongly associated with waste water treatment effluent discharge is not new. The Arkansas Department of Pollution Control and Ecology, Water Division (ADPCE 1995) reported results of a study on water quality and biological response in Sager Creek in response to the effects of waste water discharge into the creek from the City of Siloam Springs. Stream samples were collected between July 1993 and June 1994 above and below the point of Siloam Springs waste water treatment plant effluent discharge into Sager Creek. The work was done in response to objections by the State of Oklahoma to proposed discharge permit modifications. Water quality samples were collected and analyzed for total P (and other parameters) approximately once every two months during the one-year study. Two sample sites bracketed the waste water treatment plant: site SAG07 was located 500 ft above the outfall, and site SAG09 was located 500 ft below the outfall. The median (of six samples) total P concentration was 0.06 mg/L at site SAG07, which increased dramatically to 1.38 mg/L at site SAG09, presumably due to the influence of the effluent contribution to the stream. In addition, samples were collected during a low-flow period on June 28, 1994 and during a high-flow event on November 16, 1993. During both flow regimes, stream concentrations of total P were relatively low upstream from the treatment plant, but dramatically higher (especially during low flow conditions) at the site (SAG09) immediately downstream from the waste water discharge (Figure 5-4). During high flow conditions, the concentration of total P increased by more than a factor of 1.5 from immediately above to immediately below the WWTP; during low flow, the difference was more than a factor of 20.

Haggard et al. (2004) reported soluble reactive P (SRP) concentrations immediately downstream of WWTPs on Spring Creek and Sager Creek in the IRW in July 2002. Concentrations of SRP in stream water below the respective WWTP exceeded 1.5 mg/L in Sager Creek and 6 mg/L in Spring Creek; these concentrations were more than an order of magnitude higher than at the sampling locations above the WWTPs and more than an order of magnitude higher than the water quality standard for Scenic Rivers in Oklahoma. Haggard et al. (2004) concluded, based on their study and also numerous other literature citations that:

> ***Phosphorus concentrations in streams generally show a sequential decrease with increasing distance from municipal WWTP effluent discharge.***

Thus, the importance of WWTPs to stream P concentrations in the IRW and elsewhere is not new information. This has been well known for a long time (See studies cited by Ekka et al. (2006) and study by Haggard et al.(2003). Ekka et al. (2006) published an in-depth study of waste water P contributions to streams and stream chemistry in 2002 and 2003 from the cities of Fayetteville, Rogers, Springdale, and Siloam Springs in NW Arkansas. Effluent discharge significantly altered water chemistry, including P concentration, in Mud Creek, Osage Creek, Sager and Flint Creeks, and Spring Creek. These are all tributaries to the Illinois River within the IRW. Mean discharge (stream flow) downstream from the effluent inputs increased from 2 to 57 times compared with the discharge measured upstream of the WWTPs. This illustrates that these headwater streams are effluent dominated. The Fayetteville and Rogers WWTPs discharged water with average total P concentrations of 0.25 and 0.35 mg/L during the study period into Mud and Osage Creeks, respectively. The Springdale WWTP discharged an average effluent TP concentration of 4.4 mg/L into Spring Creek. Average effluent P concentration was not available from the Siloam Springs facility, but it appeared that the change in dissolved P concentration in Sager and Flint Creeks was somewhere between those of Spring Creek and Mud or Osage Creeks (Ekka, 2006). Results from this study showed that stream SRP concentrations increased several fold downstream from effluent inputs (Table 5-1). The most profound effect of WWTP effluent on stream P values was in Spring Creek, which had the highest SRP concentration measured in the study (7.0 mg/L in August 2002). This is more than 189 times higher than the 0.037 water quality standard that is applicable to the main stem rivers in this watershed. Ekka et al. (2006) concluded from his study of streams in the IRW that:

> ***point sources such as municipal waste water treatment plant (WWTP) effluent discharges still exert a prominent influence on dissolved phosphorus (P) concentrations and transport in Ozark streams, particularly in northwest Arkansas, USA** (several cited references)*

Effluent discharges increase the concentration of P in the water column, and also increase P in the stream sediment (Ekka et al. 2006 and numerous other citations provided by Ekka et al. 2006). As a consequence, Ekka et al. (2006) concluded that:

> ***The influence of WWTP effluent discharge on benthic sediments is generally much greater than other external factors, such as agricultural land use and nonpoint source pollution in the Ozarks (Popova et al. 2006).***

The ability of stream sediments to adsorb P is often much less downstream from effluent discharge points, compared with locations upstream (Ekka, 2006). This can cause P concentrations in stream water to be higher, in response to inputs from any source, as a consequence of the P contributed to the stream sediments from the effluent discharge.

Haggard et al. (2003c) sampled 30 stream sites in the IRW from 1997 to 2001, including sampling sites on the main stem Illinois River, Clear/Mud Creeks, Osage Creek, and Spring Creek. They concluded that:

> ***The spatial distribution of these sites clearly identified elevated P concentrations at the Illinois River at Highway 59*** *[near the Arkansas/ Oklahoma border]* ***were likely from a single WWTP*** *[Springdale]* ***over 46 kilometers upstream… Over 35% of the P transported during surface runoff conditions was likely from resuspension of P retained by stream sediments. Thus, these sediments may represent a considerable transient storage pool of P after management strategies are utilized to reduce elevated P concentrations at the Illinois River.***

Dr. Olsen claimed, based on his principal components analysis (PCA), that samples for which his first principal component (PC1) was equal to or above his designated cutoff value of 1.3 exhibited what he identified as a unique poultry waste signature. Yet his own data show that base flow stream sites having PC1 above 1.3 are largely located immediately downstream of urban areas and WWTPs (Glenn Johnson 2008, his Figure 3-16). Based on this observed spatial pattern, Dr. Glenn Johnson (2008, page 56) concluded:

> ***Whatever is driving PC1 … it is in large part coming from areas of high human population, in absence of poultry***

Defendants' expert, Dr. Jarman (2008) documented contributions of P and fecal indicator bacteria to the IRW as permitted discharges from WWTPs, accidental bypasses/overflow releases, and land application of biosolids. He also provided data illustrating a poor history of responsiveness by Oklahoma regulatory agencies in dealing with violations by point sources which caused contributions of these constituents to surface waters in the IRW. The importance of point source contributions of nutrients to streams in the IRW have been well recognized at least since the 1980s (Jarman, December 2008). Plaintiffs' consultants have under-emphasized the continued importance of point source contribution in this watershed, by failing to recognize the clear association of P concentrations in streams within the watershed with locations of WWTPs, selectively deleting (without properly clarifying the effects of this action on key conclusions) from some of their analyses sites that were downstream from WWTPs (Dr. Engel, 2008), and choosing a human per capita P production rate at the lower end of available estimates (Ms. Smith and Dr. Engel, as per Figure 8 in Jarman, 2008).

Phosphorus concentrations in WWTP effluent were higher in the past than they are currently because of more recent P limitations placed on effluent and because of the elimination of phosphate laundry detergent. The manufacture of phosphate detergent for household laundry was ended voluntarily by the industry in about 1994 after many states, including Arkansas, had established state-wide phosphate detergent bans (Litke, 1999). After WW II, powdered clothes washing detergents were about 15% P by weight. In 1970, the industry limited the P content to 8.7% by weight in response to national concerns about eutrophication. In 1971, five cities in Illinois limited P-containing laundry detergents. The number of states having phosphate detergent bans increased steadily after 1971, up to 26 states by 1995. During the 1940s, the total P concentrations in raw household waste water effluent averaged about 3 mg/L, increasing to about 11 mg/L at the height of phosphate detergent use about 1970, and have since declined to about 5 mg/L (Litke, 1999).

Although substantial progress has been made in reducing point source contributions of P to streams in the IRW, it is likely that many of the improvements are only recently having an influence on water quality. In the mid-1990s, Arkansas and Oklahoma state agencies and cities agreed to consider methods to reduce P inputs by 40%, and P limitations were placed on WWTPs in the IRW (Jarman, December, 2008). However, for most treatment plants, these changes were not fully implemented until about 2003, and some still do not have discharge limitations (Jarman, December 2008). Therefore, the influence of these point source reductions may not be evident in much of the available water quality data for this watershed, especially the data collected prior to about 2003. Defendants' expert, Dr. Jarman reported approximately a 40% decline in P contribution in WWTP effluent in the IRW between the period 1997 -2003 and the period 2004-2007. This decrease corresponded with approximately a 40% decline in the concentration of P in base flow stream water in the Illinois River at Tahlequah, near the upper end of Lake Tenkiller (Connolly 2008).

Despite these substantial improvements in P contribution from WWTP point sources to streams in the IRW, even for the WWTPs that do now have more stringent P limitations, these limitations of 1 or 2 mg/L of TP in the effluent are still 27 to 54 times higher than the 0.037 mg/L standard for the Scenic River sections of the stream system in the IRW.

Nelson et al. (2003) estimated P loads and concentrations in the Illinois River at the Highway 59 bridge crossing in Arkansas, near the Oklahoma state line, and compared them with loads and concentrations estimated for five other streams. They found that their estimates of base flow concentrations of total P for five of the six watersheds (all except Moores Creek) were similar (near 0.25 mg/L), and stated:

> ***This is a possible confirmation that the base- flow concentrations are effected by wastewater treatment plant discharges, as Moores Creek is the only watershed without a permitted WWTP discharge.***

The WWTPs in Springdale, Fayetteville, Siloam Springs and Rogers have all agreed to reduce effluent total P concentrations to less than 1 mg/L (Ekka et al. 2006). Nevertheless, this voluntary reduction, if fully implemented, will still allow effluent discharged from these facilities into IRW streams to contain total P that is 27 times higher than the 0.037 mg/L standard.

WWTPs are not the only potential municipal sewage point sources of nutrients and fecal indicator bacteria to streams within the IRW. Jarman (2008) documented problems associated with the Watts total retention (lagoon) waste water treatment facility, which is situated within a quarter of a mile of the main stem Illinois River in Oklahoma, adjacent to the Arkansas state line. Although there is no effluent discharge from this sewage treatment facility, there is still the risk of pollution contributions to the river due to land application of treated sewage. The land application area associated with this facility is located within about 100 feet of the river. The U.S. Fish and Wildlife Service (USFWS) expressed concerns over a proposal for the Watts facility to begin taking waste water from the city of West Siloam Springs. The USFWS concern centered on application of treated waste water to hydric soils in the flood plain of the Illinois River. Jarman (2008) reported an accidental release of 275,000 gallons of treated waste water from the facility in 1999, which resulted in assessment of a $20,000 penalty by ODEQ. An assessment prior to this accidental release by Enercon Services, Inc, in a study commissioned by the Oklahoma Attorney General and the OSRC, concluded that:

> ***its proximity to the River and the presence of numerous pathways virtually assures that the Illinois River will be the target of and ultimate recipient of the contaminants associated with the Watts lagoon.*** (cited in Jarman 2008)

It is important to note that, even though municipal sewage treatment facilities, such as WWTPs and the Watts lagoon, constitute an overwhelmingly important source of nutrients to stream water, they are not the only important sources of NPS water pollution associated with urban development. Runoff from urban areas also is well known to contribute substantial amounts of fecal indicator bacteria, nutrients, sediment, and other constituents to drainage water. Urban sources of these constituents can include fertilizer use on lawns and parks, pet and urban wildlife waste, erosion associated with construction activities, and broken or leaking sewer pipes.

Urban areas contain relatively high proportions of impervious land (i.e., parking lots, compacted soils on construction sites, roofs, roads, sidewalks, etc.), from which contaminants of all kinds can be rapidly flushed to streams during rain storms. Urban areas are specifically designed so as to move rain water quickly and efficiently to streams in order to prevent flooding. This is typically done via installation of extensive systems of storm drains, gutters, and roadside ditches. An unfortunate effect of such rapid routing of runoff into streams within urban areas is that there is much less opportunity for constituents such as P and fecal indicator bacteria, which tend to be removed from infiltrating water and retained on soils, to be removed from the runoff before it enters a stream. In urban areas, less water is routed through soils; more water is routed overland. As a consequence, proportionately more P and bacteria are carried from the land into the stream. This concept is not new; it is not specific to the IRW. Rather, it is a well-known facet of NPS pollution science. It was ignored by the Plaintiffs' consultants in this case.

Novotny (1995, page 23) concluded that urbanization is probably the greatest source of NPS pollution to streams. Nevertheless, it was not considered by Plaintiffs' consultants in targeting their sampling or interpreting much of their resulting data. Urbanization changes the hydrology of the watershed to favor transport of pollutants from the land surface to streams. Lawn fertilizers, pet waste, and urban wildlife waste are flushed into storm drains, bypassing the soils that might otherwise adsorb some of the contaminants present in that water. Soil loss to erosion from construction sites can reach magnitudes of over 100 tons per hectare per year. For that reason, construction occurring in only a small percentage of the watershed can contribute a major portion of the sediment carried by streams in the watershed (Novotny 1995, page 25). This sediment contributes directly to elevated suspended solids and turbidity; it also carries P. Novotny (1995, page 24) cautioned that newly developing urban lands (which are very common in the IRW) should receive special attention in NPS assessment:

> ***this stage of land is characterized by the high production of suspended solids caused by erosion of unprotected exposed soil and soil piles…Extremely high pollutant loads are produced from construction sites if no erosion control practices are implemented. Therefore, in establishing pollutant loadings relative to land uses, one must determine first whether the area is fully developed or if it is a developing area and/or significant construction activities are taking place therein.***

Novotny's caution is especially relevant to NPS pollution in the IRW. As described in Section III.3 of this report and by Grip (2008), new construction is widespread in the IRW, and northwest Arkansas has been in recent years one of the fastest growing metropolitan areas in the United States.

With an increase in the amount of impervious surfaces in response to urbanization, the urban portions of the watershed become more hydrologically active. Runoff events carrying heavy pollutant loads become more common (Novotny, 1995, page 27). Pollutants that accumulate in the streets, parking lots, and areas of compressed soil are readily transported in surface runoff. These pollutants can include dust and soil particles (which can be high in P content), animal waste, atmospherically deposited nutrients, and fertilizers. High-density urban zones are nearly completely impervious and have very limited capacity to attenuate pollution, with almost all emitted pollutants eventually reaching surface waters (Novotny and Olem 1994, page 493). Novotny (1995, page 45), based on EPA's Nationwide Urban Runoff Project (NURP), estimated that the event mean concentration of TP in urban runoff for the median urban site was 0.37 to 0.47 mg/L, with the 90th percentile urban site yielding an event mean concentration of TP equal to 0.78 to 0.99 mg/L. The TP in urban runoff would be expected to be partly from erosion and partly from other P contributions associated with such factors as fertilizer use, pet waste, leaking or faulty sewer lines, urban wildlife, and other sources.

Data from EPA's National Urban Runoff Program (U.S. EPA, 1983) found that the median urban stream site in the United States received storm runoff having total P concentration of 0.37 (10 times higher than the Illinois River standard) to 0.47 mg/L, with 10% of values more than twice as high (Novotny 1995, page 61). EPA (1983) further concluded that:

> ***Fecal coliform counts in urban runoff are typically in the tens to hundreds of thousand per 100 ml during warm weather conditions, with the median for all sites being around 21,000/100ml.***

For comparison, the median concentration of fecal coliform bacteria in streams sampled in the IRW by Plaintiffs' consultants in areas representing a variety of land uses and reported in Dr. Olsen's database was 130 cfu/100 ml.

It has been previously shown that nutrient exports from urban watersheds can be as high, or higher, than exports from agricultural lands. For example Osborne and Wiley (1988) investigated land use and stream water quality in the Salt Fork watershed in Illinois, which is primarily (90%) agricultural. Urban areas accounted for 5% of the total watershed areas, which (as in the IRW) was concentrated in the upper watershed. They found that:

> ***Despite the over-riding dominance of agricultural land use within the Salt Fork watershed, our results demonstrate that urbanization rather than agriculture has the greatest impact on stream SRP concentrations.***

The Illinois River Management Plan (OSRC, OSU, and NPS, 1999) concluded that:

> ***Urban runoff is recognized as one of the major non-point sources of pollutants within watersheds. The Illinois River Corridor is a mixture of moderately populated urban areas with a large growing suburban and rural population.***

Urban land use has also been associated with negative impacts on stream biological integrity. For example, Wang et al. (1997) found that urban impacts on stream biological integrity in Wisconsin became severe when the percent of the watershed covered by urban land use exceeded 10% to 20%. Effects have been associated with the amount of impervious surface area, amount of developed land, and population density (Klein 1979, Benke et al. 1981, Jones and Clark 1987, Lenat and Crawford 1994).

Parsons and University of Arkansas (2004) characterized water quality and aquatic biological resources of several streams in the IRW. The objective was to provide data to U.S. EPA for use in evaluating potential 303(d) listings of water quality impairment for Arkansas. They concluded that multiple stressors are affecting this system at all times. Water chemistry nutrient results at locations downstream from WWTPs were nearly always higher in nutrient concentrations than the respective upstream location. Of the 12 sites assessed in the IRW for this study, one was classified as "severely impacted" and two were classified as "impacted" on the basis of multiple chemical and biological indicators of environmental health. The severely impacted site was located on Spring Creek below the Springdale WWTP. One of the impacted sites was located on Muddy Fork below the Prairie Grove WWTP. The other impacted site was located on Osage Creek, below urban development and multiple WWTP discharge locations.

According to data compiled for this case by Defendants' expert, Dr. Ron Jarman, WWTP effluent within the IRW usually contains about 10 to 40 cfu/100 ml, on average, of FCB. Nevertheless, effluent discharged directly into the Illinois River system sometimes contains levels that exceed the 200 cfu/100 ml Primary Body Contact Recreation standard, including values in the thousands of cfu per 100 ml. Such values of bacteria in the effluent from WWTPs contribute to the overall bacterial concentrations in the streams within the watershed.

Routine operation of WWTP facilities contributes well known point sources of P and fecal indicator bacteria. In addition to these routine contributions, there are numerous accidental releases of these constituents to the stream system. The accidental release of raw or partially treated sewage is not an unusual event in the collection system of a WWTP. This can introduce large amounts of nutrients and fecal indicator bacteria to stream waters. Jarman (2008) noted that there are many causes for these events, including line breakage, blocking or plugging of the lines, construction damage, heavy rainfall, and system breakdowns at a lift station or the WWTP. Such events represent a recurring source of nutrients and fecal bacteria in urban settings.

Dr. Jarman documented sewage bypasses (uncontrolled discharge of untreated or partially treated sewage) within the watershed over a period of seven years. Although data were not available from all townships within the watershed, and data were only available for some years in others, Dr. Jarman reported about 700 hours of sewage bypass with average concentrations of FCB in the range of 1.5×10^{15} (one and a half thousand trillion) or higher per bypass event (Table 5-2). Most of these bypasses involved raw sewage, in volumes that averaged 500 gallons (Westville) to 9,060 gallons (Lincoln). I have become aware of additional bypass data that were not included in Table 5-2, indicating two bypasses from the Stilwell facility comprised of 1 million and 800,000 gallons of raw sewage. These bypasses data were discussed by Dr. Madden in his September, 2008 deposition for this case (Madden 2008, deposition transcript, pages 61 to 71). Thus, sewage bypasses constitute an important additional source of fecal bacteria to stream water in this watershed.

Mixed land use watersheds often have mainly forests in the upper reaches, and urban and agricultural land uses in the lower reaches. Therefore, contaminants that might be contributed to the streams from humans and their activities and their livestock often increase in a downstream direction, from the headwaters to the larger streams that are found downstream. The IRW is fairly unusual in that urban development is concentrated mainly within the headwater areas of the watershed (See Figure 3-1). For that reason, stream waters in the IRW tend to have relatively high concentrations of P and fecal indicator bacteria even within the upper stream reaches. This makes it difficult to evaluate the relative importance of different sources of contaminants found in the non-urban areas in this watershed. The Comprehensive Basin Management Plan for the IRW (Haraughty 1999, page 30) correctly identified that:

> ***...much of the phosphorus comes from the headwaters of the watershed, thus remediation efforts should concentrate in this area.***

Stream water data collected by Plaintiffs' consultants for this case clearly show the dominant influence of urban areas in general, and WWTPs in particular, on stream total P concentrations and to a lesser extent stream *E. coli* concentrations. Figure 5-5 illustrates the spatial patterns in total P concentrations in the IRW during low flow conditions, based on the geomean of 5 or more samples calculated from Dr. Olsen's database. The same pattern is seen for Dr. Olsen's data when samples collected under all flow regimes are included (Figure 5-6).

The water quality standard for P in the IRW is frequently exceeded even under low flow conditions (Figure 5-5), at times when NPS pollution associated with activities on pasture lands would not be expected to contribute appreciably to stream water quality. Such exceedances of the P water quality standard during low flow are probably caused primarily by point sources of pollution, mainly waste water treatment plant discharge from municipalities, directly into streams within the watershed. All of the low flow geomean P values that were relatively high were based on samples collected downstream from a developed area and downstream from a WWTP.

Dr. Olsen's database contains fewer samples analyzed for *E. coli*, so for those maps the criterion was relaxed to include all sites for which there were at least three (rather than 5) samples on which to base the geomean calculation. Geomean *E. coli* results for base flow and for all flow conditions are shown in Figures 5-7 and 5-8, respectively. Although there are fewer sample locations that met the criterion for number of samples, the patterns are similar. Again, the highest geomean concentrations tend to be located downstream from urban areas and WWTPs.

Thus, with nearly 300,000 people living in the IRW, mostly in urban areas in the upper watershed, there are clearly substantial sources of fecal indicator bacteria and nutrients to streams that flow through these urban areas. Plaintiffs' own data show this. The scientific literature shows this. Attempts to place most of the blame on land application of poultry litter (or any other source in the non-urban portions of this watershed) simply makes no sense.

6. Within non-urban areas in the IRW, there are many potential sources of P and fecal indicator bacteria to stream waters.

In addition to urban sources of NPS pollutants to streams in the IRW, described above, there are also multiple potential sources of P and fecal indicator bacteria to stream waters within the non-urban portions of the watershed. Plaintiffs' consultants **assume** that poultry litter application is the only, or the dominant, source in non-urban areas. They do not adequately assess the importance of the other potential sources. These other potential sources include, in particular, cattle manure, septic systems, roads and associated ditches and culverts, and other livestock and wildlife. Plaintiffs' consultants largely ignore or dismiss these other well-known potential sources of NPS pollution.

Cattle Manure

Cattle grazing is well known to be an important source of NPS pollutants to streams (Clark et al. 1999). In view of the large number of cattle in the IRW (Clay 2008), the importance of cattle as contributors of P and fecal indicator bacteria to streams in the IRW must be evaluated in any credible assessment of NPS pollution. Plaintiffs' consultants did not perform such an evaluation. Rather, they assumed that cattle could not be major contributors to NPS pollution because cattle consume forage, which contains P, and then excrete it within the pasture system. Thus, Plaintiffs' consultants conclude that cattle do not bring new P into the watershed, and therefore that they cannot be responsible for transport of P and fecal indicator bacteria to the stream system. This line of reasoning is flawed because it totally ignores the importance of transport processes and the tendency of cattle to transfer, via their grazing and movement patterns and access to streams, P and fecal indicator bacteria from the upland pasture areas to the stream itself or to the riparian zone adjacent to the stream, from which these constituents can much more readily be transported to stream water during a rain storm. This process is more fully explained in Sections III.11 and III.9 of this report. There are approximately 200,000 cattle, calves and milk cows in the IRW, based on agricultural census data compiled and provided to me by Dr. Billy Clay (pers. comm. 2008). I have observed that these animals commonly have access to streams and stream banks in the IRW. Clearly, they defecate directly into surface water, or defecate on land immediately adjacent to surface water (Clay 2008). Thus, fecal matter from livestock is both directly deposited into streams and is deposited to riparian zones where it is highly susceptible to surface transport from land to stream during rainstorms. In contrast, fecal matter in poultry litter, when the litter is properly applied, is not deposited in, or in proximity to, surface water or in areas that are likely to generate saturated overland flow from the pasture surface to the stream.

Cattle are widely distributed throughout the IRW, although the densest concentrations occur in proximity to the urban areas in the upper reaches (eastern portion) of the watershed (Figure 6-1). Because these livestock are so numerous and widely distributed, and because they occur in and immediately adjacent to streams in some areas, they cannot be ignored in evaluating fecal indicator bacteria and nutrient source issues in this watershed. The failure of Plaintiffs' consultants to fully consider the potential effects of cattle on the concentrations of P and fecal indicator bacteria in streams represents a major flaw in their analyses of water quality in the IRW.

Livestock pastures are well known sources of NPS stream pollution. Dismissal by Plaintiffs' consultants of the importance of cattle to NPS issues in the IRW is not consistent with the position taken by the Illinois River Management Plan (OSRC, OSU, and NPS 1999). The Management Plan concluded that:

> ***Unconfined livestock in the Illinois River Corridor have directly affected stream and riparian habitats. Removal of vegetation, trampling of streambanks and wading in shallow streambed areas has led to bank instability, increased erosion and sedimentation, and alteration of habitat.***

Plaintiffs' consultant, Dr. Berton Fisher, did not evaluate the extent to which cattle serve as a transport mechanism for taking P that was contained in living pasture grass and transporting it into or near water courses, although he acknowledged that cattle:

> ***can assist in that process.*** (September 4, 2008 deposition testimony, page 450-451)

Often, it is not the grazing intensity on the land that determines the extent of stream water pollution associated with cattle; rather, it is the unrestricted access of cattle to water that has the major impact (Novotny, 1995, page 23). I have observed that cattle in the IRW commonly have access to streams, and that cattle access to streams appears to be more widespread on the smaller tributaries than it is along the main stem Illinois River.

It has been reported in the scientific literature that P concentrations in runoff from intensively managed dairy pasture can be as high as 7.36 mg/L (Nash and Murdoch 1997, cited in Haygarth and Jarvis 1999). Previous studies have found increased concentrations of nutrients in streams draining pasture land; for example, pasture in the Ozarks Highlands region of Missouri is associated with increased stream concentrations of nutrients, suspended solids and algal levels relative to forested areas (Perkins et al. 1998).

Cattle grazing in riparian areas can cause erosion and movement of P into stream waters. Butler et al. (2006) found that vegetative ground cover has a large impact on the volume of surface runoff and P export from pastured riparian areas. Riparian areas with bare ground contributed substantial amounts of sediment and P to surface waters during heavy rainfall.

Plaintiffs' consultant, Dr. Fisher, testified in his deposition (September 4, 2008) about an email that he received from Shannon Phillips from the Oklahoma Conservation Commission (labeled as Exhibit 27) which documented:

> ***elevated nutrient concentrations and dramatic increases in periphyton growth***

attributed by Ms. Phillips to cattle grazing in Cedar Hollow, a subwatershed of the IRW which was believed to not have received land application of poultry litter.

Dr. Olsen testified in the Preliminary Injunction hearing that he could discriminate among poultry, WWTP, and cattle as sources of constituents in water in the IRW, but he did not articulate a specific criterion (such as his principal component (PC) 1equal to or greater than 1.3 cutoff that he used to determine poultry impact) to assign a water sample to the cattle impact category. Dr. Glenn Johnson (2008, pages 40 to 50) describes in detail how Dr. Olsen's arguments changed from the Preliminary Injunction stage of this case to his September, 2008 deposition. As Dr. Johnson shows, all four of Dr. Olsen's cattle-impacted samples had PC1 greater than 1.3, above his unique poultry waste signature threshold, and Dr. Olsen was unable to obtain separation in his PCA analyses between cattle and poultry impact. When confronted with new evidence regarding PCA results for samples that Dr. Olsen believed to be cattle impacted, his opinion that cattle are not an important source in the IRW never changed, only the line of reasoning that he needed to adopt to reach that conclusion. In the final analysis, it appears that Dr. Olsen believes that cattle cannot be important sources of constituents to stream water because he is unable to see a strong signal in his PCA. As described in Section III.12 and in the expert reports of Dr. Glenn Johnson, Dr. Larson, and Dr. Chadwick, Dr. Olsen's PCA is not a scientifically legitimate tool for excluding cattle, or any other potentially important nonpoint source, as significant in this watershed.

I located 11 bacterial TMDL reports that were completed for the Oklahoma DEQ and that provided an estimate of what constituted the most important source of fecal bacteria to the subject watersheds. The locations of the watersheds for which those TMDL reports have been completed are shown in Figure 6-2. Together, they cover much of the state of Oklahoma, including watersheds to the north and south of the IRW, including areas of intensive poultry farming. Four of the 11 TMDL reports (Boggy Creek, North Canadian River, Lower Red River, and Little River) stated that livestock was estimated to constitute the largest contributor of fecal coliform bacteria loading to land surfaces AND that cattle appeared to be the most likely livestock source of fecal bacteria to streams. All of the remaining 7 TMDL reports stated that cattle appear to represent the most likely or largest source of fecal bacteria. Thus, there are 11 TMDL reports completed for the state of Oklahoma, of which I am aware, that single out one source of fecal bacteria as being most important. **All** of those single out cattle. If cattle represent the major source of fecal indicator bacteria in these watersheds, it is logical to assume that they may also represent an important source of P. It therefore seems curious that Plaintiffs' consultants dismiss the importance of cattle in the IRW based on the weak argument that cattle merely recycle P already present within the watershed (See detailed discussion of this issue in Section III.17 of this report) and Dr. Olsen's inability to find a strong signal for cattle waste in his PCA analysis (See discussion of the numerous problems with Dr. Olsen's PCA in Section III.12). In fact, the density of cattle in the IRW is generally equal to, or greater than, the densities of cattle in these 11 Oklahoma watersheds for which TMDL analyses suggested cattle as being recognized as the most likely source of fecal indicator bacteria (Figure 6-3).

Not only are cattle known to be important sources of NPS pollution to streams, but in addition, reducing the amount of time that cattle spend in streams and riparian zones via installation of off-stream watering sources has been shown to dramatically decrease bank erosion and improve stream water quality in cattle-impacted streams. For example, Sheffield et al. (1997) installed a watering trough and subsequently documented decreased cattle use of the adjacent stream in Virginia. Stream bank erosion was reduced by 77%. Flow-weighed total P concentration in the stream outlet decreased from 0.2 mg/L to 0.07 mg/L, a decrease of 65%. Total suspended solids were reduced by 89%. Fecal coliform bacteria concentration was reduced by 51%. Similarly, in a study of BMP effectiveness on dairy farms in Oregon, Sullivan et al. (2004) demonstrated a reduction by about 74% in FCB concentrations in stream water for a stream that passes through pasture land subsequent to installation of best management practices that included riparian fencing and off-stream watering for cattle. Plaintiffs' consultants contend that cattle are not important contributors of fecal indicator bacteria and other constituents to streams because they merely recycle nutrients that are already present on pasture land. If this was true, it would not be possible to improve water quality conditions via improved cattle management. Improved cattle management, via BMP installations, is a major focus of watershed restoration work nationwide. Federal and state governments and stakeholder groups spend considerable resources on these efforts. The reasons for this are simple: cattle are important contributors of NPS water pollution; improved cattle management contributes to improved water quality. It seems unbelievable to me that Plaintiffs' consultants do not understand this.

Septic Systems

Septic systems are often considered to be one of the most common and significant sources of stream pollution in rural residential areas (Novotny and Olem, 1994, page 483). Stream pollution from septic systems is primarily due to two pathways: 1) subsurface transport of mobile pollutants such as nitrate via shallow discharge of aquifers into the receiving water, mostly during base flow, and 2) movement of septic effluent to the ground surface when the septic system is not functioning properly (Novotny and Olem, 1994, page 483).

My analyses suggest that approximately 76,000 (Table 4-1) people in the IRW live in communities that do not have central waste water treatment facilities. These people can be assumed to have septic systems for disposal of their household waste water. An unknown percentage of these septic systems are not adequate to protect surface water quality.

According to the Illinois River Basin Plan (Haraughty 1999), constructed by the Oklahoma Conservation Commission for the portions of the IRW that lie within Oklahoma, up to 75% of the septic systems in portions of the IRW may be inadequately constructed or situated. In addition, Engineering Services, Inc. (2004) reported results of septic system surveys in Tontitown and Highfill, Arkansas. They found that 43% of surveyed septic systems in Highfill and an unknown percentage in Tontitown had reported failures, including surfacing sewage, sewage backup, and surface discharge of gray water. Less than 30% of the septic systems had valid permits.

Thus, there is reasonable basis for assuming that an appreciable percentage of the septic systems that serve roughly 76,000 inhabitants of the IRW have some problems associated with their operation or location. As a consequence, it is probable that septic systems can contribute substantial amounts of P and fecal indicator bacteria to streams in the watershed. This source of P and fecal indicator bacteria to streams in the IRW was not fully considered by Plaintiffs' consultants in this case. In addition, Plaintiffs' consultants did not collect any samples in the IRW that were intended to shed light on movement of P, fecal indicator bacteria, or other constituents from septic systems into streams within the watershed.

Bacterial TMDL analyses conducted for ODEQ routinely include an assessment of septic system contribution to overall bacterial loads to rivers in Oklahoma that are 303(d) listed for fecal indicator bacteria. These include the following TMDL reports:

- Canadian River (Parsons 2006b, 2008d)
- North Canadian River and Shell Creek (Parsons 2006a)
- Lower Red River (Parsons 2007c)
- Neosho River (Parsons 2008c)
- Washita River (Parsons 2007a)
- Little River (Parsons 2007d)
- Arkansas River Segments and Haikey Creek (Indian Nations Council of Governments 2008)
- Sans Bois Creek (Parsons 2008a)
- Boggy Creek (Parsons 2007b)
- Upper Red River (Parsons 2008b)

Plaintiffs' consultants did not conduct any analyses to determine the potential impacts of septic systems in the IRW. Dr. Fisher acknowledged in his September 4, 2008 deposition (pages 513-514) that such an effort was not part of his analysis in this case.

Given the rather routine inclusion of potential septic system contributions of fecal indicator bacteria to streams as part of the TMDL process conducted for ODEQ in watersheds throughout Oklahoma, an assessment of nonpoint sources within the IRW should include an evaluation of the potential importance of septic systems as sources of NPS pollutants in this watershed. Such an evaluation was not conducted by Plaintiffs' consultants in this case.

Plaintiffs' consultant, Dr. Engel, actually found a significant relationship between the presence of septic systems and stream P concentration in his analyses of a set of comparative subwatersheds. He dismissed, without any reasonable basis, the relevance of this finding as an artifact of the cross-correlation between poultry house density and septic system distribution. In fact, he could have just as easily dismissed the relevance of his correlation between poultry house density and stream P concentration as an artifact of the same cross correlation. See further discussion of this issue in Section III.8 of this report. In Dr. Engel's Appendix G, he presents less than two pages of analysis that provide the foundation for his dismissal of his observed strong correlations between septic system density and stream P concentrations in his high flow basins in the IRW. He states that:

> ***The Oklahoma Department of Environmental Quality (1997) investigation of septic systems in the Illinois River concludes "systems identified in this study were found to pose no apparent threat to the quality of the Illinois River."***

Examination of that ODEQ (1997) report yields a very different picture than was presented by Dr. Engel. First, the ODEQ (1997) report consists of only six pages of text, some site maps, and tables; it includes no in-depth analysis of anything. Second, the study did not investigate residential septic systems (except where multiple residences used the same system); rather, it focused on 59 non-residential septic systems (i.e., schools, stores, taverns, etc), three community waste water treatment plants, and eight pit privies. Data were collected over a two-week period in July 1997 by interviewing system owners/operators. No field data were collected: no water samples, no runoff evaluation, no evaluation of possible system malfunctions, no determination of stream water quality in proximity to the sites included in the study. Not one of the tens of thousands of individual residential septic systems in the IRW was included. Data were collected by interview; such data included the type of system, type of use, number of users, etc. Distances between each of the 59 systems studied and the nearest stream were calculated. ODEQ's estimates of probable flow in these non-residential systems were generally low, and the systems evaluated were mostly located a fair distance from the nearest stream. On this basis, ODEQ (1997) concluded that these investigated systems posed no apparent significant threat. No conclusions were drawn by ODEQ regarding any potential threat from the tens of thousands of individual residential septic systems in the IRW, either individually or collectively. Dr Engel's contention that this study provides adequate basis for his dismissal of the importance of septic systems in the IRW is without merit.

Dr. Engel also attempted (page G-1 of his expert report) to evaluate P load from septic systems in his 14 study subwatersheds, and claimed that his calculations showed that P load in the small study streams exceeded P loads from the residential septic systems in those watersheds. Even if his calculations are correct, this reveals nothing about the importance of septic systems watershed-wide in the IRW. Furthermore, Dr. Engel appears to not understand that the overall load within the watershed does not determine the extent of possible stream contamination; pathways for pollutant transport must also be considered, and were not considered by Dr Engel in his inadequate assessment of the potential for septic systems to contribute pollutants to streams in the IRW. Furthermore, it is not reasonable to assume that there is one primary source of P contribution to streams in this watershed, given the mix of land uses and large numbers of people and animals. Plaintiffs' consultants' apparent search for evidence that might incriminate one source type is not defensible. There are many source types; each is widely distributed; the relative importance of sources in one area is not necessarily the same as the relative importance in other areas. In his Appendix G, Dr. Engels concludes:

> ***Based on this analysis and the Oklahoma Department of Environmental Quality report on septic systems [**discussed above**], the septic systems in the high flow watersheds are not the primary source of P exports in runoff and baseflow.***

Again, Dr. Engel's search for the "primary source of P exports" is conceptually flawed before he begins his analyses.

As detailed above, Dr. Engel provides little information that would actually help in a determination of how important septic systems are to P contributions to streams throughout the watershed. The ODEQ study contributes no useful information for addressing this question. The loads calculations offered by Dr. Engel ignore the importance of transport from source location to stream, the diversity of conditions across the landscape, the large number of septic systems that occur in the IRW, and the overwhelming likelihood that a great many NPS sources (rather than one "primary" source) are involved in contributing P to stream waters in the IRW.

Erosion

It has been well recognized for more than 25 years that erosion is an important source of NPS water pollution. Novotny (1980) stated:

> ***Since a major portion of nonpoint pollution is associated with sediment, understanding the process of erosion and sediment movement and deposition is important.***

Nevertheless, Plaintiffs' consultants did not undertake a study of erosion and erosion sources of P in the IRW. Plaintiffs' consultants' collection and analysis of sediment cores from Lake Tenkiller is insufficient as a basis for quantification of watershed sources of P associated with erosion. This is, in part, because sediment is retained at multiple locations throughout the watershed. The failure of Plaintiffs' consultants to conduct an assessment of erosion and associated P is a substantial oversight, given the extensive amount of construction-related land clearing actions within the watershed in recent years, as well as the extensive network of roads and the access to streams of large numbers of cattle, which trample vegetation and thereby cause erosion from riparian areas. All of these are issues and actions that would be expected to accelerate erosion within the watershed. None of them were adequately addressed by Plaintiffs' consultants in their sampling program or interpretation of data.

Erosion is a common and well known source of P to stream water. Erosion is not specific to urban or to agricultural land, but rather occurs watershed-wide. Nevertheless, there are certain types of land use that tend to promote higher levels of erosion than others. These are the land uses that disturb soils and remove vegetative cover.

Suspended sediment loads of many rivers have increased up to 10-fold as a result of land use changes in the watershed (Novotny 1995, p. 112) . The activities that cause the most disturbance, and therefore the highest amount of erosion, are generally known to include deforestation, construction site erosion, and intensive agriculture (including row crops and high concentrations of livestock in feedlots or on pasture lands) on highly erodible lands (Clark 1985, Novotny 1995,

p. 112). Among the various environmental effects of increased erosion is the fact that sediment carries nutrients, including P, and metals. Large amounts of sediment in stream waters originate from urban areas (Novotny 1995, p. 114). Sediment yields from urban developing areas can be very high, reaching values up to 50,000 tons of sediment per square km per year (Novotny 1980, 1995, page 115).

It has long been recognized that movement of P from the land to stream water is often caused largely by erosion (Smith et al. 2001, Weld et al. 2001). Erosion can be associated with any land disturbing activity within the watershed. All land disturbing activities can therefore result in the addition of sediment to streams. In a study of North Carolina streams, construction activities caused the highest erosion rates (Lenat and Crawford 1994). Erosion is also often strongly associated with the presence of roads, especially dirt roads, and the ditches and culverts that are found along and across roads. Land clearing activities, including logging, road building, and row-crop agriculture, have long been known to be important sources of sediment to streams (cf., Birch et al. 1980). Such erosion-causing activities can result in substantial contributions of P to drainage water (Hobbie and Likens 1973, Birch et al. 1980, Sullivan et al. 1998a, Sullivan et al. 1998b). For example, Hobbie and Likens (1973) found a 12-fold increase in P flux in a deforested watershed compared with its control. Cattle and other livestock that are permitted uncontrolled access to riparian areas cause sloughing of stream bank soils and elimination of stream bank vegetation (Novotny and Olem 1994, page 683). Pastureland becomes a source of NPS pollution when proper erosion control practices are not in place or when livestock are allowed to approach or enter surface waters. Overgrazing and permitting livestock to approach and enter water courses are major polluting activities on pastures and rangelands. Novotny and Olem (1994, page 686) concluded that, if such activities are controlled, pollution from pastures and rangelands may be minimal.

There are 5,169 miles of road in the IRW, 54% in Arkansas and 46% in Oklahoma, based on U.S. Census data for 2000. Of the roads in the IRW within Arkansas, about 52% are paved and the remainder are dirt, gravel, or otherwise unimproved roads (U.S. Dept. Commerce, Census TIGER files for the year 2000). Dirt roads generally contribute more erosion than do paved roads. The unpaved roads, in particular, can be important sources of erosion to streams, and that erosion can carry large quantities of P. In some watersheds, erosion from roads and other disturbances can constitute the dominant source of total P in streams (Sullivan et al. 1998a,b).

Roads in the IRW contribute an unknown amount of sediment-associated P to streams. In addition, because of the impervious nature of road surfaces, they can undoubtedly be effective vehicles of transport to streams for fecal indicator bacteria deposited on the road surface. Plaintiffs' consultants did not assess the importance of roads, or of other important erosion sources, as potential contributors of NPS pollutants to streams in the IRW.

In addition to erosion from construction sites, roads, and associated ditches and culverts, stream bank erosion can be an important source of sediment to streams, along with its accompanying P load. Stream bank erosion is typically dependent on soil characteristics and the extent to which riparian vegetation is disturbed. Trees and some species of shrubs and herbaceous plants tend to have extensive root systems that help maintain the integrity of the stream bank and limit bank erosion. Cattle grazing in the riparian zone, which is prevalent in the IRW, reduces the vegetative cover, thereby increasing the potential for bank erosion to occur. The Oklahoma Conservation Commission's Comprehensive Basin Management Plan for portions of the IRW within

Oklahoma (Haraughty 1999, page xi) recognized the importance of this issue, and concluded that:

> ***Bank erosion along the Illinois River and its tributaries poses a substantial threat to the system. Eroding banks provide sediment, gravel, and nutrients which destroy valuable land, degrade water quality, destroy critical aquatic habitat, and eventually fill in Lake Tenkiller. This bank erosion is often caused by elimination or poor maintenance of the riparian zone, bridge construction, upstream or downstream changes in channel morphology and/or various upstream land use changes. Estimates of the loading from the bank material suggest that eroding banks contribute a significant amount of the total nutrient load in streams…***

This conclusion was based on evaluation of several sources of data on bank erosion in the IRW, including characterization of selected stream bank areas, estimation of long-term erosion from aerial photographs, and results of a short-term bank erosion study. It was estimated that, overall, the Illinois River became an average of 18% wider between 1979 and 1991, as a consequence of bank erosion. Haraughty (1999, page 44) estimated that 3.5 million tons (62 million cubic feet) of material was eroded into the river from the stream bank between 1979 and 1991. The Baron Fork once sustained a canoe float industry, but has become too shallow to canoe as a consequence of erosion (Haraughty 1999, page 101). Given the importance of erosion in the IRW, and the fact that its importance is well-recognized and described in the OCC's Comprehensive Basin Management Plan, it is improper that Plaintiffs' consultants would ignore this issue in formulating their sampling plan and in interpreting NPS issues in this watershed.

Grip (2009) also provided estimates of bank erosion along a 59-mile stretch of the Illinois River from Lake Frances to Lake Tenkiller. Grip (2009) estimated, based on examination of maps and aerial photographs, that over 15 million cubic yards of sediment have been relocated within this section of river since 1972. Grip (2009) stated that he would expect that only a fraction of that eroded sediment has reached Lake Tenkiller. Studies of sedimentation rate in Lake Tenkiller would be expected to only reflect a portion of the erosion contributed to the Illinois River and its tributaries; the balance would remain in the stream channels and various impoundments that exist in the watershed.

Novotny (1995, p. 115) concluded that the most important sources of erosion include land-disturbing agriculture (especially when spring rains fall on frozen soils), urban areas (especially exposed bare soils and street dust), road construction, logging, strip mining, and stream bank erosion (especially associated with loss of riparian vegetative cover). Neither poultry operations nor pasture lands were listed by Novotny (1995) as being among the most important sources of erosion, although livestock access to riparian zones and to stream channels adjacent to pastures can be important.

Erosion tends to transport primarily the fine particle (clay) and organic matter fractions of the soil from land to stream water. These can be relatively rich in P. Therefore, eroded soil is often enriched in P by a ratio of two or more as compared with particles that remain behind in the soil (Brady and Weil 1999, page 547).

Nutrient enrichment of lakes has been shown to result from NPS inputs associated with conversion of land from native cover to agriculture and urban land use (Stoermer et al. 1993, Schelske and Hodell 1995, Reavie and Smol 2001, Jones et al. 2004). Croplands have been shown to be particularly well correlated with nutrient concentrations in streams (Perkins et al.

1998) and reservoirs (Jones et al., 2004) in Missouri. For example, Jones et al. (2004) found that the percent cover of croplands explained 60% to 70% of the variation in the concentrations of total P and total N in Missouri reservoirs.

Novotny and Olem (1994, p. 247) concluded that general land disturbance by agriculture or construction can increase erosion by two or more orders of magnitude (factor of 100 or more). They further concluded that the highest rates of erosion typically result from deforestation, construction site erosion, and intensive agriculture on highly erodible lands (Novotny and Olem 1994, page 248).

The potential for soil erosion and associated nutrient export increases with soil disturbance (Pitois et al. 2001). Disturbed soils are more exposed to the weather and therefore prone to erosion. Erosion generally controls the movement of particulate P in landscapes (Sharpley et al. 1993). The particulate P movement on agricultural land is a complex function of rainfall, irrigation, runoff, and soil management factors that affect erosion.

Erosion associated with roads has been studied in Arkansas. For example, the Watershed Conservation Resource Center (2005) assessed the contribution of sediment from unpaved roads in three subwatersheds of the Strawberry River watershed in Arkansas, using the U.S. Forest Service Water Erosion Prediction Project modeling module. The study watersheds have a total area of 92 square miles. A survey was conducted of 10% of the publicly owned unpaved roads to determine slope, distance between water diversions, width, road characteristics, presence of ruts, presence of ditch vegetation, fill width, and fill grade. These variables provided inputs to the modeling effort, along with soil texture and rock content, climatic data, and traffic levels. The sediment loads from publicly and privately owned unpaved roads were estimated to be 1,500 tons and 1,412 tons (+/- 50%), for a total of 2,912 tons/yr. Averaged across all unpaved roads in the study area, the estimated sediment entering a stream was 18.8 tons per mile per year.

There are 80 miles of publicly owned and 64 miles of privately owned unpaved roads in the study area considered by the Watershed Conservation Resource Center (2005). The total unpaved road density is 1.6 miles of road per square mile. This compares with more than 1,300 miles of unpaved road in the Arkansas portion of the IRW, yielding an unpaved road density of 1.8 miles of unpaved road per square mile of watershed in the Arkansas portion of the IRW. Thus, the density of unpaved roads in the Arkansas portion of the IRW is slightly higher than is the density of unpaved roads in the portions of the Strawberry River watershed in Arkansas, for which it was estimated that nearly 19 tons of sediment enter the stream system through erosion each year for each mile of unpaved road.

Harmel et al. (1999) also recognized that bank erosion has introduced concern about resource conditions of the Illinois River. They conducted a study of a 101 km stretch of the river from Lake Frances to Lake Tenkiller to quantify erosion rates. Short-term erosion was measured with bank pins and cross-section surveys after four 2- to 2.5-year return period flow events between September 1996 and July 1997. The cumulative erosion from these four rain events averaged 1.4 meters. Long-term erosion was evaluated from aerial photographs taken in 1979 and 1991. Lateral erosion during that 12 year period averaged 16 m, or 1.4 m/yr on 132 eroding stream banks.

Other Potentially Important Sources

There are likely more than 200,000 large mammals (livestock and wild deer; Clay 2008) in the IRW, in addition to the approximately 200,000 cattle discussed above. These other livestock include, in particular, swine, horses, and sheep (Clay 2008). In some instances, these livestock have direct access to streams and riparian zones. In other instances, livestock manure is land applied (Clay 2008). The potential for these animals to contribute P and fecal indicator bacteria to streams in the IRW was not fully addressed by Plaintiffs' consultants.

Wildlife is a well-known contributor of NPS pollutants, especially fecal indicator bacteria, to streams. Myoda (2008) discusses the importance of wildlife as a bacterial source in the IRW.

Many species of wildlife preferentially utilize riparian or stream habitat, thereby increasing the likelihood that fecal material will be deposited in, or immediately adjacent to, streams. Plaintiffs' consultants did not fully consider the importance of wildlife as potential causes of fecal indicator bacteria above water quality standards in streams of the IRW.

Based on the affidavit and materials provided during the Preliminary Injunction hearing by Plaintiffs' consultant, Dr. Lowell Caneday (2008), there are approximately 155,500 recreationists per year on the Illinois River in Oklahoma. Although I make no attempt to verify or substantiate Dr. Caneday's estimate, there clearly are many recreationists using this river, especially during the summer recreation period, May through September. Toilet facilities have not been adequate to support such river use (Haraughty 1999), especially given the high estimate of the numbers of people who float the river (76% of total users) and are therefore away from developed facilities. The volume of human waste deposited along the river and the shores of Lake Tenkiller by these users, and the potential for such waste to contribute P and fecal indicator bacteria to the stream system was not evaluated by Plaintiffs' consultants for this case. Analyses reported by Defendants' expert, Dr. Jarman (2008) include findings of substantial recreational use within the watershed over a period of 40 years and resulting contribution of P and fecal bacteria.

Plaintiffs' consultants focused their attention on land application of poultry litter in the IRW, but largely ignored land application of swine manure, commercial fertilizer, and biosolids as potential sources of P and/or fecal indicator bacteria. There are about 166,000 swine in the watershed. This population represents a large quantity of fecal material which is probably land applied (Clay 2008), presumably partly in the watershed. Plaintiffs' consultants did not collect any samples or conduct any analyses in an attempt to determine the importance of any of these potential sources of land applied fecal materials and chemical fertilizers as contributors to stream water quality. I do not have information on the locations of land applied swine manure or commercial fertilizer in the IRW. Dr. Jarman determined the general locations of biosolids applications. Application areas generally correspond with locations of waste water treatment plants.

Lake Frances

Lake Frances is a man-made impoundment located on the main stem Illinois River in Oklahoma, along the Arkansas state line. The dam that forms Lake Frances was breached in about 1990. As a consequence, soft sediment that had been deposited in the former lake bed during the years of reservoir impoundment are now part of the flood plain and are more available for erosional processes to contribute some of this sediment (along with its P load) to the river. This would be expected to occur primarily during high flow conditions. Thus, the old Lake Frances lake bed is now a potential source of sediment, P, and other constituents to the Illinois River as it crosses the state line from Arkansas into Oklahoma (Haggard and Soerens 2006).

It is likely that the Lake Frances lakebed stored P in its sediments, especially during the years when P concentrations in the river were high (Haggard and Soerens 2006). This stored P can now be released back into the river when dissolved P in the water is less than equilibrium P concentrations with the sediment. In addition, resuspension of P-enriched sediment, due to wind (Søndergaard et al. 1992) or high stream flow can increase the concentration of P in stream or lake water.

Based on experiments using lake sediment cores from Lake Frances, Haggard and Soerens (2006) found that bottom sediments in Lake Frances have the ability to release phosphate into the river water. They measured sediment P fluxes under aerobic conditions that rivaled those measured under anaerobic conditions in many eutrophic reservoirs. They concluded:

> ***Thus, bottom sediments in Lake Frances have the potential to release high amounts of P and also to maintain P concentrations downstream at the Illinois River elevated above Oklahoma's Scenic River TP criterion (0.037 mg/L)...It is possible that remediation strategies should be considered for Lake Frances and the P- rich sediments stored within the former impoundment, if Oklahoma's Scenic River TP criterion will be achieved.***

To the best of my knowledge, Plaintiffs' consultants have not considered the influence of Lake Frances on TP concentrations in the Illinois River in any of their analyses.

Nevertheless, the potential importance of Lake Frances as a source of P to the Illinois River has been recognized for some time. The Comprehensive Basin Management Plan, prepared by the Oklahoma Conservation Commission (Haraughty 1999) stated:

> ***The collapse of the Lake Frances Dam in 1991 resulted in an additional source of nonpoint source pollution to the Illinois River basin in Oklahoma. The collapse exposed several hundred thousand cubic meters of nutrient-enriched lake bed to potential erosion.***

Haraughty (1999, page 53) went on to state, in discussing Lake Frances:

> ***It is difficult to imagine that water quality in the river can be much improved until this situation is addressed as a high potential exists for release of sediment to the river.***

The extent to which P is contributed to the Illinois River by Lake Frances was examined in a study by Parker et al. (1996). Samples of river water were collected at the Highway 59 bridge crossings above (n=130) and below (n=94; near Watts) the state line over a one year period in 1995 and 1996. Weekly samples were collected and augmented with additional storm samples. The average total P above the lake was 0.28 mg/L and below the lake it was 0.33 mg/L. Parker et al. (1996) reported that:

> ***The percent difference of 16.4% and t-test results of 0.059 for TP give borderline results as to whether a difference exists in the upstream and downstream TP concentrations.***

Thus, results of the statistical comparison were inconclusive. It is noteworthy, however, that the difference in the average results between the two stations was actually larger than the 0.037

mg/L water quality standard for TP. This suggests that if there were no sources of TP in Arkansas at all, the concentration of TP in the Illinois River in Oklahoma, just downstream from the Arkansas state line, might exceed the water quality standard solely on the basis of P contributed at the Lake Frances location, and the adjacent contributing area, between the two Highway 59 bridge crossings. Parker et al. did find a statistically significant increase (by 42%) in the concentration of total suspended solids (TSS) from the upstream to the downstream sampling location, supporting the hypothesis that the former Lake Frances lake sediment may be eroding and contributing sediments to the Illinois River.

Haggard and Soerens (2006) evaluated P release from sediments that had previously accumulated in Lake Frances. Haggard and Soerens (2006) stated:

> ***State agencies at the Arkansas-Oklahoma River Compact Commission reported conflicting trends in P concentrations and loads at the Illinois River during 2002, where P was decreasing in Arkansas and increasing in Oklahoma. One potential confounding factor in the water-quality monitoring programs between states may be that Arkansas monitors the Illinois River upstream of a small impoundment*** *(Lake Frances)* ***and Oklahoma monitors downstream from the spillway.***

Sediment equilibrium P concentrations in laboratory studies were found to range from 0.05 to 0.20 mg/L, which is greater than the total P standard applicable to this river from the Lake Frances outlet downstream through Oklahoma. Haggard and Soerens (2006) speculated that P that had been previously stored in the Lake Frances sediments during the years when P concentrations in river water were especially high, are now being released from sediment into the river water column. This would be expected to occur, in particular, when dissolved P in the river is less than sediment equilibrium concentrations, and when oxygen is depleted at the sediment/water interface or sedimentary P is introduced back into the water column by wind resuspension of bottom sediments. The latter process is known to occur in shallow, nutrient-rich lakes (Søndergaard, 1992). In discussing their findings, Haggard and Soerens (2006) concluded:

> ***This study showed the potential for bottom sediments in Lake Frances to increase P transport at the Illinois River, especially if water column dissolved P concentrations upstream from Lake Frances decrease…***

<u>Summary</u>

It is clear that there are a multitude of point and nonpoint sources of P and fecal indicator bacteria to the IRW. The Oklahoma Conservation Commission's Comprehensive Basin Management Plan for portions of the IRW that occur within Oklahoma (Haraughty, 1999) stated:

> ***However, agriculture cannot be cited as the sole source of water quality problems in the watershed... Additional nonpoint sources include recreation, the remains of Lake Frances, urban runoff, gravel mining, and streambank erosion. Combined sources*** *(sources with essentially both point and nonpoint source pollution)* ***include nurseries and urban runoff.***

The importance of these, and other (i.e., pets, row crops, hobby animal husbandry), widely distributed sources is cumulative. Some may also be important individually. For example, Haraughty (1999, page xiii) concluded that a single nursery on the shores of Lake Tenkiller contributed more than 1% of the total P load to the lake in irrigation return flows alone (irrespective of storm contributions), although controls have more recently been placed on the irrigation water at this site.

The Illinois River Management Plan (OSRC, OSU, and NPS 1999) recognized the importance of these multiple sources of NPS water pollution in the IRW. They identified a series of management goals aimed at corridor values, recreational resources, and water quality. The listed water quality management goals included:

- Minimizing alteration of stream habitat and sedimentation due to destabilization of stream banks,
- Reducing the loading of nutrients and chemicals from commercial nursery tailwater and pollutant loading into the river from urban runoff,
- Reducing nutrient inputs due to animal waste by requiring producers to complete and implement approved conservation plans,
- Protecting riparian areas from the impacts of livestock,
- Assisting in the collection of water quality data and public education.

Since the management plan was written in 1999, positive steps have been taken to address many of these goals. But it is important to note that the focus outlined for these management goals recognized that there are many contributors to NPS water pollution in the IRW, not one. Plaintiffs' consultants' claims that land application of poultry litter constitutes "the primary source" do not agree with results of previous assessments.

The importance of these various sources of constituents to streams in the IRW was almost completely overlooked by Plaintiffs' consultants. For example, Dr. Glenn Johnson (2008, page 71) reported the results of his evaluation of Dr. Olsen's PCA analyses. He stated that Dr. Olsen's SW3 and SW22 PCA runs included only 15 samples presumed or collected with the intent of characterizing sources other than poultry (2 cattle edge-of-field, 3 cattle impacted springs, 4 WWTPs, and 6 Tahlequah urban stream samples). Every one of those samples exhibited PC scores that fit Dr. Olsen's criterion for indicating what he characterizes as his unique poultry waste signature. Even if Dr. Olsen's signature does provide some interpretable information regarding contributions of various constituents to water in the IRW, it does not indicate what the source or sources of those constituents might be. Dr. Olsen largely ignored or seriously under-represented in his analyses most of the sources expected to be significant contributors in this watershed.

7. *The Plaintiffs' consultants contend that P, fecal indicator bacteria, and other constituents move directly from pasture to stream, but they do not demonstrate such movement. They incorrectly claim that their edge-of-field samples demonstrate such movement.*

<u>Plaintiffs' Consultants Did Not Exhibit a Clear Understanding of What Their Edge-of-Field Samples Were Intended to Represent, and Did Not Exhibit an Understanding of How to Interpret Their Edge-of-Field Data.</u>

Any P or fecal indicator bacteria that do reach a stream from a land-based source of these constituents can then be transported downstream. During that transport, some bacteria die and others settle to the bottom and are incorporated into the stream sediment, from which they can be re-suspended during high flow periods or where they may die or be consumed. Some P can also settle to the stream sediment, especially in ponded areas such as Lake Frances, located on the mainstem Illinois River in Oklahoma, near the Arkansas border. Thus, as you move downstream, the concentrations of both P and bacteria often decrease unless there are substantial additional source areas. This is an important point because it cannot be assumed that fecal indicator bacteria contributed to the Illinois River system in Arkansas will necessarily survive long and far enough to enter the sections of the river in sufficient numbers as to cause the concentration to exceed standards at the locations where most of the recreational use occurs.

Turner and Leytem (2004) developed extraction procedures to assess the chemical characteristics and potential behavior of P in the environment. Although they stated that phosphates in manures and runoff are correlated following recent manure land application, they also cautioned that phosphates can be strongly retained in soil if drainage occurs downward through the soil profile. In addition, they stated that:

> ***Hydrological factors, including the pathway taken by runoff as it leaves the field, must be considered when assigning the risk of phosphorus transfer from recently applied manure (Haygarth and Jarvis 1999).***

It has long been recognized that P is not very mobile in soils. In fact, Haygarth and Jarvis (1999) quoted a book by Sir John E. Russell from 1957 that described P as being "insoluble in water", which resulted in it "staying in the surface soil apparently forever". Although this statement was an obvious oversimplification, it serves to emphasize the fact that P is not very mobile in soils.

10. *The concentrations of P and fecal indicator bacteria in stream water are strongly dependent on water flow, such that concentrations tend to be much higher under high flow conditions as compared with low flow conditions. In addition, concentrations of fecal indicator bacteria in the IRW tend to be above geomean standards primarily in the smaller (those that I classify here as third order and smaller) streams, and less often in the larger (those that I classify here as fourth order and larger) streams. These patterns have implications regarding how P and fecal indicator bacteria data should be analyzed and interpreted.*

<u>Effect of Stream Flow</u>

The dependence of P and fecal indicator bacteria concentrations on stream flow and stream order is important for several reasons. First, there are fewer river recreationists during storm periods when flows are highest and fecal indicator bacteria concentrations are highest. Second, river recreation is focused mostly on the larger streams (Plaintiffs' consultant Dr. Caneday Preliminary Injunction testimony), which tend to have lower concentrations of fecal indicator bacteria. Thus, most recreationists are not exposed to the concentrations of fecal indicator bacteria found to occur during high flow events or in the small streams. Third, the measured concentrations of fecal indicator bacteria and P in stream water are heavily dependent on the flow conditions at which the samples were collected. This makes it difficult to document changes over time or to identify locations where water quality standards might be violated, especially if samples are collected such that they are not representative of the normal range of flow conditions or if the frequency of sampling at high versus low flow changes during the monitoring period.

Evaluation of bacteria concentration data for river or stream water must consider the influence of stream flow on bacteria sources. The concentration of FCB or *E. coli* in water within watersheds containing mixed land use varies directly with flow such that concentrations tend to be higher when flow is high and concentrations tend to be lower when flow is low. It is well known that this occurs essentially everywhere. The reasons why this is true have to do with the mechanisms by which fecal bacteria from all sources move from the landscape to flowing water. High flow provides the opportunity for some waste water treatment facilities to become overloaded with runoff water, creating a sewage bypass, and also provides the transport mechanism to move bacteria from all land-based sources to the water. This pattern is well illustrated using data collected by the USGS (Figure 10-1), which show that the concentrations of FCB and *E. coli* in the Illinois River near Tahlequah are generally below both the respective geomean standards and the respective individual (or 10% of individual) sample standards when river flows are low. However, fecal indicator bacteria samples are often above the standards when flows are high, especially when they are above what I define here as "high flow" to include flows above the 70th percentile of long-term (January 1980 to May 2007) daily average flows recorded by USGS at this site. In other words, 30% of the daily average flows are above the value used to discriminate between high flow and other than high flow, and 70% are below it. The shaded portion of the panels in this figure indicates data collected during high flow periods; nearly all of the bacteria concentrations above the standards at this site, which is located just upstream from Lake Tenkiller, occurred during high flow.

Therefore, one should not try to evaluate changes over time (trends) in fecal indicator bacteria concentration without taking flow into consideration. Furthermore, bacteria concentrations in the Illinois River tend to be above standards primarily at times when one would expect minimal river recreation to be occurring (during rainy periods with high river flows).

In Figure 10-2, I show USGS data from the Illinois River near Tahlequah, OK, showing changes in the geomean concentration of FCB, *E. coli*, and total P over time. At first glance, it might appear that something happened after 1999 that dramatically increased the level of fecal indicator bacteria and P concentrations in the Illinois River. The geomean concentrations for all three constituents increased dramatically after 1999. That first impression is incorrect. The USGS changed its sampling procedures in 1999, such that fixed interval sampling was replaced by sampling that was intended to capture storm events. Thus, the data collected prior to 1999 are not comparable with the data collected after 1999 unless flow is considered. The effect of flow on fecal indicator bacteria and P concentrations can be illustrated by examining the data at this site, expressed as individual sample occurrences, where each sample is coded according to river flow at the time that the sample was collected (Figure 10-3). For this analysis, high flow again represents flows in excess of the long-term 70th percentile flow value; moderate flow represents flows between the 30th and 70th percentiles; and low flow represents flows below the 30th percentile of the long-term flow record.

The concentrations of fecal bacteria indicators in the Illinois River are strongly related to water flow, such that concentrations of bacteria above the geomean standards occur primarily during periods of high flow. Under low flow conditions, when I would expect that most on-river recreation (i.e., canoeing) occurs, FCB and *E. coli* tend to be below the geomean standards

(Figure 10-2). This has important implications regarding how surface water fecal indicator data should be analyzed and interpreted.

Figures 10-2 and 10-3, showing different representations of the same data, collected by the same agency, from the same location illustrate a number of important points. Contrary to the highly misleading graphic offered by the Plaintiffs in the Preliminary Injunction hearing, purported to indicate an increasing trend over time in bacterial concentrations in the Illinois River, there is no indication in the USGS data that fecal indicator bacteria or total P concentrations at this site have increased over time. Rather, the large differences in concentrations recorded during the various years are mainly determined by the number of high flow samples that were collected. For years during which many high flow samples were collected, the bacteria concentration values (including the geomean of the values) were relatively high. For years during which few high flow samples were collected, the bacteria and total P concentration values were relatively low. Many more samples were collected by USGS during high flow conditions during the years post-1998 (Figure 10-4). Any representation by the Plaintiffs that such data reflect a pattern of increasing fecal indicator bacteria or total P concentration over time is not accurate.

Point sources of water pollution, such as WWTPs, contribute constituents, including P, to stream water under all flow regimes. During high flow periods, it is also possible for constituents such as P and fecal indicator bacteria to move as nonpoint source contributions from some land locations to streams. Point sources can also contribute to concentrations in stream water under high flow conditions because high flow can re-suspend P that had been deposited in the stream sediments when flows were low. This mechanism was documented by Haggard et al. (2001) in Spavinaw Creek, Arkansas. They concluded that:

> ***the P adsorbed to benthic*** [stream bottom] ***sediments may be resuspended into the water column and transported downstream during storm runoff events… Perhaps the most important finding in this study is the pronounced impact that Columbia Hollow [***WWPT plant***] has on P retention in Spavinaw Creek. P retention efficiency in Spavinaw Creek was reduced by a factor of 30 below Columbia Hollow***

Similarly, Haggard et al. (2003b, page 191) concluded that:

> ***Almost half of TP transported in streams during storm events may be resuspended from bottom sediments (Svendsen et al. 1995). Release or resuspension of P associated with stream sediments in the Illinois River may be a critical source because this stream receives P inputs from several wastewater treatment plants in the headwaters."***

Ekka et al. (2006, page 389) stated that:

> ***During storm events, dissolved and total P transport may be influenced by resuspension of point sources of pollution. Suspended sediments in streams affect dissolved P equilibrium between water and benthic sediments (House et al. 1995) and likely impact dissolved P concentrations occurring during surface runoff events in streams"***

Pickup et al. (2003), in a USGS report on P in the IRW, concluded that P concentrations generally increased with runoff, and they offered as possible explanations for this: P resuspension from the stream bed, stream bank erosion, and the addition of P from nonpoint sources. In contrast to the interpretation of Pickup et al. (2003), one might erroneously conclude from the reports of Plaintiffs' consultants that resuspension from the stream bed, stream bank erosion, and a variety of NPS pollution sources are unimportant and nearly all NPS P is derived from poultry litter.

There are numerous temporary sinks for P in stream systems. These include P adsorption to sediment, various impoundments, and uptake from the water column by microbes and aquatic plants (cf., Haggard et al. 2004). As a consequence, some of the P that is contributed by point sources during low flow conditions can be stored in the sediment and biological communities and then remobilized into stream water if the P sources become reduced or during high stream flows (Haggard et al. 2004).

Recreational activities in the IRW (described by Plaintiffs' consultant Dr. Caneday (2008) and Defendants' consultant Dr. Dunford (2008)) are primarily those covered by secondary body contact recreation, such as wading, canoeing, boating, and fishing. The Illinois River is primarily a floating river, rather than a swimming river. The primary body contact recreation standards for fecal indicator bacteria apply to full immersion, which does occur in the IRW, but which is generally infrequent and short-lived (Dunford 2008). Secondary standards are generally five times higher than primary standards (Gibb 2008, page 11).

Effect of Stream Order

Streams within the watershed are commonly classified according to Strahler stream order, which reflects the relative size of the various streams. The smallest tributaries in the upper portions of the watershed are first order. As the first order stream flows downhill, it combines with other first order streams. Once two first order streams combine, they form a second order stream. The process continues in a downstream direction to higher orders (Figure 10-5). In the IRW, most streams range from first order to sixth order (Figure 10-6) based on the National Hydrography Dataset; a short segment of the Illinois River is classified here as seventh order below the confluence with the Baron Fork. First order streams tend to be very numerous and very small. In general, they were not sampled by Plaintiffs' consultants in their stream sampling efforts for this case. In Figure 10-6, I show the locations of streams within the watershed that are second order and larger. The rafting section of the Illinois River is sixth order according to this scheme.

It can be useful to break down the sampled streams within the watershed into stream order classes, because some conditions vary with stream order. For example, the geomean *E. coli* concentrations measured by Plaintiffs' consultants in the IRW tend to be higher for the smaller (lower order) streams as compared with the larger streams. The geomean from Plaintiffs' database of the measured *E. coli* concentrations in fourth, fifth, and sixth order streams are below the geomean standard for primary body contact recreation (Figure 10-7). I expect most of the stream recreation to occur on these larger streams, and they generally have lower *E. coli* concentrations than do the smaller streams where I expect less stream recreation to occur.

11. *In order for land applied P to have an ecological impact on a stream, it must be physically transported from the site of land application to the stream. P and fecal indicator bacteria are not uniformly contributed to streams via runoff from pasture lands, but rather are disproportionately contributed from hydrologically active areas. These are portions of the landscape that contribute most of the overland flow to streams during rain storms. Overland*

Plaintiffs' consultants failed to recognize or ignored the current science on these issues.

Researchers know that there are reasonably well-defined "hot spots" that constitute the primary source areas for P and fecal indicator bacteria contributions from pastures to streams. It is not known what percentage of the pasture land area in the IRW may actually pose a high risk of P transport to streams. Plaintiffs' consultants did not perform such an analysis, and they failed to compare any of their GLEAMS model output to field-scale data collected in the IRW. They didn't even compare their field-scale model output to their edge-of-field data, perhaps because they did not have a good understanding of what their edge-of-field data actually represented. See further discussion of this in Section III.7.

A screening analysis using a P site index was developed and evaluated on seven farms in Delaware by Leytem et al. (2003). Although the authors concluded that additional validation remained to be performed, the results suggested that the vast majority (78%) of the fields evaluated were in the low risk category for contamination of stream water.

Runoff refers to the total loss of water from a watershed by all surface and subsurface pathways (Sharpley et al. 2003a). This includes overland flow and shallow horizontal flow that eventually returns to the surface; together these constitute surface runoff. Runoff is not uniform across the landscape. Surface runoff from one field, or a portion of one field, can enter a ditch or stream, flow into another field, percolate down into the soil, or flow into an agricultural pond. Such runoff may or may not directly enter the stream system. In order to determine the potential for runoff from a given field to impact the water quality of the stream system, one must evaluate not only the extent to which overland flow occurs, but also the connectivity of the field to the stream system. Plaintiffs' consultants did not undertake to determine this, either for individual fields or for their edge-of-field samples.

As discussed more fully in Section III.19 of this report, current national and also Oklahoma and Arkansas State guidelines and regulations discourage or prohibit the spreading of poultry litter on pasture lands in the IRW in areas likely to be hydrologically active and at times when runoff is most likely to occur, thereby minimizing the possibility of stream water contamination. These guidelines and regulations were explicitly designed for the purpose of minimizing the possibility of NPS pollution of streams from the spreading of poultry litter on pasture lands. I am not aware of any comparable restrictions on cattle grazing; in much of the IRW, cattle appear to have free access to streams and to streamside areas.

Dr. Fisher stated in his September 4, 2008 deposition (page 633), when asked:

> Q. ***And I think you testified earlier, if you get a lot of rainfall, you'll get runoff. What is a lot of rainfall?***
>
> ***A. More than two inches in 24 hours. I think that's kind of a rule of thumb around here.***

It is noteworthy that the available data indicating overland flow transport of P in experimental studies were typically collected with a minimum of 2 inches in one hour, rather than in 24 hours. It seldom rains with such intensity in the IRW. Rainfall simulation studies have been conducted to quantify P movement from soil to runoff water, but such studies typically employ rainfall intensities that are higher than normally occur during rain storms within the IRW. For example Kleinman et al. (2002) applied 7 cm/hr (2.8 inches per hour) artificial rain and measured P flux in experimental boxes. Butler et al. (2006) studied sediment and P export to streams from

Contamination of surface waters in the IRW with P and/or fecal bacteria is an extremely complex issue. There are many sources of both constituents and they are widely distributed. They are not confined to a single land use or practice. There is no one-size-fits-all explanation for the occurrence of concentrations of total P and fecal bacteria indicators above existing water quality standards in some streams within the IRW. It is likely that a high percentage of the people and the animals that live in the watershed share to some degree in contributing these constituents to surface waters. I have seen no data that would suggest to me that the spreading of poultry litter is an important cause of P or fecal bacteria indicator concentrations above water quality standards in the IRW. Where concentrations of either or both of these parameters are above water quality standards in non-urban areas, there are multiple land use activities, and multiple potential sources of P and fecal indicator bacterial contribution. Nevertheless, the most striking spatial pattern appears to be the proximity of the sites with highest P and, to a lesser extent, fecal indicator bacteria values to the location of waste water treatment plant effluent and urban development.

Dillon and Kirchner (1975) reported the following typical values for P export from comparable sedimentary watersheds:

Forest – 11.7 mg/m^2/yr

Forest and pasture – 23.3 mg/m^2/yr

Intensive agriculture – 46 mg/m^2/yr

Urban – 110 to 1,660 mg/m^2/yr

Thus, based on these data summarized by Dillon and Kirchner (1975), the export of P from urban areas is many times higher per unit land area than is the export of P from forest and pasture land.

14. *When selecting "Reference" streams, Plaintiffs' consultants incorrectly chose watersheds that are generally free of human influence, rather than those that have similar human impacts but lack appreciable poultry operations.*

Plaintiffs' consultants compared chemical and biological conditions in the IRW to hand selected "Reference" reservoirs and streams that were selected to represent relatively pristine conditions. Such watersheds are not appropriate points of reference for evaluating the influence of land application of poultry litter on water quality. Rather, appropriate reference watersheds for the scientific questions at hand in this case would be those that have similar mixes of land use to the IRW (urban, rural residential, forest, pasture lands) with similar densities of people, cows, and other animals, but few or no poultry operations. A comparison of the IRW with more appropriate reference watershed conditions for this case yields very different conclusions than those presented by Plaintiffs' consultants. My analyses show that watersheds having generally similar distributions of land use, but limited poultry operations, exhibit stream concentrations of P and fecal indicator bacteria that are generally similar to those in the IRW.

Dr. Olsen describes in his report (Olsen 2008), collection of what he terms reference waters. On page 2-23 of his report, he states that he:

> ***selected reference locations in representative watersheds that were similar to the IRW, but were not affected by poultry operations.***

through 2002. Haggard and Soerens (2006, page 281), citing the Ekka et al. (2006) study of the effects of municipal effluents on streams in the IRW, also acknowledged that P concentrations in the IRW have been decreasing over time; they credited reductions in municipal discharges for at least part of the decrease in stream P concentration.

Plaintiffs' consultants collected lake water data from Lake Tenkiller that allow an evaluation of the extent to which water quality has changed over time, although there may not be enough years of data to conclude that there have been statistically significant changes in recent years. The concentrations of total P at the lacustrine (lake-like) sampling stations, LK-01 and LK-02 in Lake Tenkiller appear to have decreased in recent years, based on data summarized by Cooke and Welch (2008, their Figure 7). I have extracted the data from Cooke and Welch's Figure 7 for the lacustrine lake sampling site closest to the dam (site LK-01) and show their measured total P values at that site (six years of data represented). Total P concentrations in the more recent years (2005-2007) were about half the values measured in the earlier years (1974, 1992, 1993; Figure 15-3). I also show in Figure 15-3 the median and quartile values of total P measured at sampling sites near the dam in each of 135 reservoirs in Missouri, reported by Jones et al. (2004). The comparable total P values measured in Lake Tenkiller during the three most recent sampling years (Cooke and Welch 2008) are lower by about a factor of two than the 25th percentile of the distribution of the Missouri reservoir data. In other words, more than 75% of the Missouri reservoirs studied by Jones et al. (2004) had total P concentrations that were much higher than Lake Tenkiller.

The more recent years for which total P data were reported for Lake Tenkiller site LK-01 by Cooke and Welch (2008) were drier than the earlier years for which they reported data, as represented by total stream discharge at the two principal downstream USGS gaging stations on the Illinois River and Baron Fork (Figure 15-4). This could cause lower concentrations of total P in lakewater because more P is generally transported to the lake under high flow conditions, which are more common during wet years, as compared with lower flow conditions, which are more common during drier years. Clearly, 1974 was a wet year, and river discharge was high. The years 1992 and 1993 were also characterized by higher river flows than the long-term median values, whereas 2006 was a drought year (both on an annual and a summer basis); 2005 was dry during summer but near the median value on an annual basis. The year 2007 was fairly typical of the long-term record. However, there were large differences in river discharge within the three most recent years sampled and reported by Cooke and Welch (2008) on both an annual and a summer basis. Total summer flow in 2007 was more than double that of either 2005 or 2006; total annual flow in 2005 was more than three times higher than in 2006, and total annual flow in 2007 was more than twice as high as 2006. Despite these large differences in flow within those three years, the concentrations of total P in the lacustrine portions of Lake Tenkiller reported by Cooke and Welch were remarkably similar in 2005, 2006, and 2007. In addition, the differences in annual flow between 2005 and 2006 were more than twice as large as the differences between 2005 and 1992. A similar pattern is seen for summer values: the difference in flow between 2007 and 2006 is larger than the difference between 1993 and 2007. It is therefore unlikely that the large decrease in total P observed between the sample occasions in the early 1990s compared with 15 years later can be attributed to differences in river flow. If that was the case, we should also see large differences in total P concentration within the more recent three year period (2005-2007); we do not. Thus, it is unlikely that the observed decrease in total P between the 1990s and the period 2005-2007 is attributable to the drier conditions observed during the more recent years of data collection.

The contamination issues documented by Conestoga-Rovers and Associates are enormously important when assessing bacteria. A very small amount of contamination can result in an erroneous measurement of bacteria that is many-fold higher than any water quality standard.

Most sampling occasions for Plaintiffs' consultants' sampling program were not observed by CRA. I therefore do not know the extent to which these kinds of violations in acceptable sampling procedures actually occurred. Those that were documented, however, suggest to me that Plaintiffs' field personnel were not adequately trained, did not have proper oversight, and did not understand how the resulting data would be used. As documented by Churchill (2008, page 9), a tracking system was not employed by the Plaintiffs' consultants to document what training was received by the field personnel and no procedure was in place to re-train personnel when changes were made to the SOPs. Furthermore, there was not a Quality Assurance/Quality Control Project Plan (QAPP) developed by Plaintiffs' consultants in advance of the field sampling efforts (Connolly 2008, Churchill 2008). This is surprising, given the size, scope, and importance of the program. Perhaps if Plaintiffs' consultants had prepared and followed a QAPP, they might have avoided some of the serious sampling errors that were made.

19. *Existing federal and state guidelines and regulations were crafted to minimize the potential for surface water and ground water contamination as a consequence of spreading poultry litter on pastureland. To the best of my knowledge, Plaintiffs' consultants have presented no evidence to suggest that farmers in the IRW are not following those guidelines and regulations, or that those guidelines and regulations are not having their intended consequence (protection of water quality).*

Current poultry litter management regulations are designed to reduce the opportunity for P transport to streams by limiting surface runoff (litter not to be applied to areas that flood, in advance of a forecasted rainstorm, or on frozen soils) and limiting connectivity to the stream channel by requiring a setback buffer from the stream, an area to which poultry litter may not be applied.

The USDA and U.S. EPA created a joint strategy to implement nationally by 2008 comprehensive nutrient management plans (CNMPs) on animal feeding operations (AFOs) in the United States. Under this strategy, NRCS was charged with implementing a new nutrient management policy (Sharpley et al. 2003b). The planning standard (NRCS 590 Standard) was re-written to include P, as well as N. In each state, NRCS state conservationists selected one of three P-based management approaches: 1) agronomic soil test P; 2) environmental soil test P thresholds; or 3) P-Index to rank fields according to their vulnerability to potential P loss. The P-Index has been almost universally adopted, with 47 states selecting this approach to target P management (Sharpley et al. 2003b).

The indexing approach ranks field vulnerability to P loss by accounting for source (soil test P, fertilizer application, manure management), and transport (erosion, runoff, leaching, connectivity to a stream channel) factors. Additional factors that can be used as the basis for individual states modifying the basic approach can include flooding frequency, soil characteristics, conservation practices, and priority of receiving waters.

In 2003, the U.S. EPA revised the Confined Animal Feeding Operation (CAFO) regulations, which apply in part to poultry operations that have been designated as CAFOs. EPA designated (page 7196) that runoff from the application of CAFO manure, litter, or process waste waters to land that is under the control of a CAFO is a discharge from the CAFO and subject to National Pollutant Discharge Elimination System (NPDES) permit requirements, except where it is an agricultural storm water discharge

All permits for CAFOs must contain terms and conditions on land application in order to ensure appropriate control of discharges that are not agricultural storm water. These Federal regulations do not attempt to regulate agricultural storm water. EPA further stipulated (Pages 7197-7198) that:

> ***When manure or process water is applied in accordance with practices designed to ensure appropriate agricultural utilization of nutrients, it is a beneficial agricultural production input. This fulfills an important agricultural purpose, namely the fertilization of crops, and it does so in a way that minimizes the potential for a subsequent discharge of pollutants to waters of the U.S. EPA recognizes that even when the manure, litter, or process wastewater is land applied in accordance with practices designed to ensure appropriate agricultural utilization of nutrients, some runoff of nutrients may occur during rainfall events, but EPA believes that this potential will be minimized and any remaining runoff can reasonably be considered an agricultural storm water discharge.***

The revised CAFO regulations require preparation of CNMPs to govern land application of poultry litter. The agency stated (Page 7213) that:

> ***With imposition of the nutrient management plan requirement, there may be a large number of CAFOs that are all trying to develop plans at the same time. Yet, there is a limited pool of certified preparers and other technical experts that are available nationwide to develop nutrient management plans and CNMPs. It is reasonable to recognize that Large CAFOs (and Small and Medium CAFOs), along with AFOs, could be competing for the services of the experts. EPA estimates there are approximately 15,500 CAFOs, including 11,000 Large CAFOs, and 222,000 AFOs. AFOs are not required to prepare CNMPs, but their access to sources of public funds, such as EQIP, may be contingent on their adherence to NRCS technical standards, including preparation of a CNMP. Thus, additional time is needed for development and implementation of the plan. Another aspect that prevents CAFOs from immediately complying with the land application BMPs is the need for States to ensure that they have established appropriate technical standards that CAFOs will use to determine the appropriate application rates for their fields. These standards must be a part of the State NPDES permitting program revisions discussed in Section V.C of this preamble. In addition, CAFOs will need some time to determine whether they have sufficient cropland for applying all of the nutrients contained in the manure, litter, and other process wastewaters that they generate. If they determine that they have excess nutrients, the CAFOs will need to identify alternatives for reducing the nutrient content, or seek markets for the excess nutrients such as off-site cropland, centralized processing facilities (e.g., pelletizing plants, centralized anaerobic digester-based power generation facilities), or other solutions. These activities cannot logically commence until the CAFO has developed the plan and knows what its allowable manure application rate is.***

Thus, EPA recognized that it takes time to implement substantial changes in regulations regarding nutrient management on lands to which poultry litter is applied. In fact, EPA subsequently delayed further the date on which the new regulations would take effect, to provide additional time beyond the intended December 31, 2006 start date. In further clarifying the timing of these changes, EPA stated (Page 7214):

> ***While EPA believes that the requirement to develop and implement a nutrient management plan will be an ''available'' technology in the near future, it is not now available for the large number of CAFOs subject to today's rule. For this reason, EPA is, in essence, today promulgating what will be the available technology for the future, similar to what the Agency did for the pulp & paper effluent guideline. See 63 FR 18604 (Apr. 15, 1998). EPA is specifying the future date of December 31, 2006 because that is the date by which it predicts that sufficient capacity and capability to develop and implement a nutrient management plan and associated BMPs will be available to the great number of regulated sources. The availability of technical experts, including certified preparers, is a critically important component of the planning requirement.***

EPA considered, but did not accept, a potential requirement for CAFOs to sample surface (i.e., stream) water above and below land application areas, in part because they recognized that there exist other, non-CAFO sources within the agricultural areas. EPA stated (Page 7217):

> ***At the time of proposal, EPA considered, but rejected, requiring CAFOs to sample surface waters adjacent to feedlots and/or land under control of the feedlot to which manure is applied. This option would have required CAFOs to sample surface waters both upstream and downstream from the feedlot and land application areas following significant rainfall. In this final rule, EPA is continuing to reject imposing surface water monitoring requirements on CAFOs through the effluent guidelines because of concerns regarding the difficulty of designing and implementing through a national rule an effective surface water monitoring program that would be capable of detecting, isolating, and quantifying the pollutant contributions reaching surface waters from individual CAFOs; and because the addition of instream monitoring does not by itself achieve any better controls on the discharges from CAFOs than the controls imposed by this rule. In-stream monitoring could be an indicator of discharges occurring from the CAFO; however, unless conditions are appropriate and a well-designed sampling protocol is established, it is equally possible that the in-stream monitoring considered at proposal would measure discharges occurring from adjacent non-CAFO agricultural sources. These non-CAFO sources would likely be contributing many of the same pollutants considered under the sampling option.***

Plaintiffs' consultants largely ignore these additional sources that occur in proximity to poultry operations and the lands to which poultry litter are applied.

In addition to the federal rules promulgated by EPA under the CAFO program, there are also state regulations and guidelines governing land application of poultry litter. Regulations have been put into place in Oklahoma and Arkansas in recent years in response to concerns about agricultural soils containing high concentrations of P. In Oklahoma, the NRCS Code 590 is the basis for the regulations. Arkansas uses a P Index to mitigate the potential for agricultural contributions of P to drainage waters. Plaintiffs' consultant, Berton Fisher, acknowledged that land application of poultry litter in the IRW is subject to the rules and regulations of Oklahoma and Arkansas (September 4, 2008 deposition testimony, page 473). He also acknowledged that, even though Plaintiffs' consultants had employed a team of observers to drive through the IRW and examine poultry operations, he was not aware of any circumstances where poultry litter has been applied in the IRW in violation of the provisions of that landowner's nutrient management plan or animal waste management plan.

Nutrient management plans are prepared to govern land application of poultry litter. They include provisions that are intended to minimize conditions that favor transport of P or fecal indicator bacteria to streams and/or to ground water.

Existing regulations and guidelines include avoidance of land application of poultry litter in pasture areas and under conditions that would be expected to increase the likelihood of either surface water or ground water contamination with some of the constituents in poultry litter, especially P and fecal indicator bacteria. The following conditions are avoided:

- Fields having high P content in the soil
- Areas that frequently flood
- Areas near a stream
- Frozen or water-saturated soil
- Shallow or rocky soil
- Steep slopes.

In addition, plans for nutrient management are developed under specific technical guidelines. Soil sampling and laboratory analysis is conducted in accordance with land grant university guidance or industry practice.

Within the pasture/hay land use areas in the IRW, soils are generally loamy. Less than 1.6 percent of these soils are classified in the USDA NRCS Soil Survey Geographic Database (SSURGO), as "clay" soils, the general class of soil particle size distribution which would be expected to promote overland flow. In addition, less than 4% of these pasture/hay soils are expected to be less than 10 inches deep, according to the average depth as reported by SSURGO. This is the depth identified by the Oklahoma NRCS Code 590 as too shallow for land application of poultry litter.

The Arkansas NRCS Code 590 (December 2004) specifies that manure shall be applied at rates to meet crop P needs when the P Index rating is High, and there shall be no manure application on sites with P Index rating of Very High. Manure application is not to occur on sites considered vulnerable to off-site P transport unless appropriate conservation practices, best management practices or management activities are used to reduce the vulnerability to P runoff. In areas with identified nutrient-related water quality impairment, an assessment shall be completed of the potential for P transport using the P Index. The results of this assessment shall be included in the nutrient management plan. Nutrient applications shall consider minimum application setback distances from environmentally sensitive areas.

Chapter 9 of the Arkansas Nutrient Management Planners' Guide (Daniels et al. Undated) provides an overview of nutrient planning in Arkansas. This document describes several sets of regulations that require livestock operations to implement plans. These include: 1) Arkansas

State Regulation 5, implemented in 1994, that requires nutrient management plans for poultry operations that had liquid manure handling systems, 2) the U.S. EPA's Confined Animal Feeding Operations (CAFO) regulations that require the states to permit CAFOs of given size, 3) Arkansas Acts 1059 and 1061 that identify nutrient sensitive areas in the state and require all nutrient applications to be done according to a nutrient management plan, including a litter management plan for poultry operations with at least 2,500 birds. Manure application rates are determined using the P Index. Setback distances are described by Daniels et al. (Undated) as follows:

> ***Dry litter applications are governed by State Title 22 as administered by ASWCC and by the Federal CAFO rules. Nutrient management protocol for Title 22 is the NRCS Standard 590 for the State of Arkansas. While Standard 590 does not specifically state setback distances, it does refer to two other NRCS standards, 633 Waste Management and 393 Filter Strips, that specifically state distances. In both cases, distances are dependent on the slope of an area next to a critical water feature (Table 9-2 and Table 9-3).***

The setback distances given in the two tables referenced above vary with slope classes and range from 20 ft for slopes less than 2% to 100 ft for slopes greater than 8% or for critical landscape features such as springs, sink holes, wells, and rock outcrops.

The Oklahoma NRCS Code 590 specifies that manure shall not be applied under the following conditions:

- areas within 100 feet of a perennial stream or pond or within 50 feet of an intermittent stream unless an established buffer strip is present that meets NRCS requirements for design and maintenance,
- areas within 100 feet of a well or sinkhole,
- fields steeper than 15% slope,
- shallow soils (less than 10 inches depth),
- rocky soils,
- soils that are frequently flooded,
- soils that are frozen, snow covered, or water saturated,
- eroding soils.

These guidelines are intended to reduce the likelihood of surface water or ground water impacts from the land application of poultry litter. They are based on current scientific understanding that recognizes that both source and transport issues are important in nutrient management. When farmers follow these guidelines, they are complying with existing laws and with current scientific understanding regarding management of NPS pollution.

Plaintiffs' consultants did not consider the extent to which existing laws and guidelines in Oklahoma and Arkansas that govern land application of poultry litter actually affect the possibility that some of the key constituents in poultry litter will move from pasture to stream. In fact, Plaintiffs' consultants totally ignored this issue. During his September 4, 2008 deposition, Berton Fisher was asked:

> ***how did the Code 590 and the state's laws on litter application factor into the forming of your opinions?***

Dr. Fisher responded:

> ***Well, I think that's accurate. They are not relevant.***

Dr. Fisher testified (pages 496 and 497) that the USDA NRCS, which drafted the Code 590 regulations, and the scientists and technicians who prepare animal waste management plans and nutrient management plans that tell farmers where, when, and how much poultry litter they can land apply in the IRW are wrong or provide guidance that is inappropriate. Dr. Fisher apparently would have the court believe that his judgment regarding land application of poultry litter should be accepted over these groups of professionals. But he provided no justification for his position that current state and federal guidance regarding land application of poultry litter is in error. He also failed to provide justification for Plaintiffs' position that land application of poultry litter, when done in accordance with current state and federal guidance, causes harm to streams in the IRW or to Lake Tenkiller.

The P-Index approach provides farmers with flexibility, giving them options for reducing the likelihood that P will move from their fields to a nearby stream. For example, Sharpley et al. (2003b) demonstrated that overall P index ratings can be decreased (lower risk of P movement to stream) by implementing specific management changes, such as changing the time of manure application, establishing riparian buffers, or reducing the feed P ration. These kinds of management actions give farmers more options, in the process of managing P transport to streams, than just reducing manure application rates (Sharpley et al. 2003b).

There are two main objectives in agricultural nutrient management: to protect water quality and to protect agricultural production and livelihoods. These two objectives jointly determine nutrient management policy. Plaintiffs' consultants ask the court to consider their misguided attempts to protect water quality, and to ignore the importance of protecting agricultural production and livelihoods.

20. *Based on examination of various reports and testimony of Plaintiffs' consultants in this case, they apparently set out to try to prove that poultry litter spreading is the cause of stream and lake pollution in the IRW. They failed to adequately consider the multitude of human activities and land uses found in the IRW that are known to be important sources of point and nonpoint pollutants to surface waters.*

There are many examples where Plaintiffs' consultants lump what is undoubtedly multiple pollutant sources into what they label as poultry-derived pollution. They minimize the influence of other known sources of point and nonpoint pollution of stream water. Thus, their analyses in many cases are not representative of the relative importance of the various potential sources of P and fecal indicator bacteria in the IRW. Rather, their effort appears to be biased so as to maximize the perceived importance of nonpoint, as compared with point, source pollution that they then attempt to assign without adequate basis to poultry operations. The study conducted by Plaintiffs' consultants for this case does not represent an objective evaluation of the relative importance of the various potentially important sources of P and fecal indicator bacteria to

> ***...we wanted even numbers of sites in low poultry houses, high poultry houses, and we decided to have five different levels of poultry houses in between so that we'd end up with sites all along our independent variable axis, which was poultry houses, our ultimate independent axis.***

21. *There is an entire field of study on factors that regulate P loss from pasture lands. Current scientific understanding reveals that P loss from fields to surface waters is controlled by a variety of factors that affect the sources of P in the field and the transport mechanisms available to move the P from source locations to streams. This research provides the foundation for current poultry litter management in the IRW. Plaintiffs' consultants ignore this body of scientific research.*

There is a large body of scientific knowledge on the potential for P to move from litter-amended pasture land to stream water. This field of research includes a large number of publications and a variety of approaches focused on field-scale assessment of risk of P movement from field to stream in runoff (www.sera17.ext.vt.edu).

More than 15 years ago, the U.S. Department of Agriculture began to develop field-scale assessment tools to assess the potential movement of P from field to stream. A group of scientists from government agencies and universities formed the Phosphorus Index Core Team (PICT) to develop a Phosphorus Index to assess the relative risk of P movement (http://www.sera17.ext.vt.edu/index.htm). The working group evolved into what is now known as SERA-17, which is a USDA Information Exchange Group, focused on P management for water quality protection. SERA-17 has published a number of policy workgroup reports and best management practice factsheets to address various aspects of this research field. Included among these is a position paper on phosphorus indices to predict risk for phosphorus losses. This position paper (available on the SERA-17 web site given above) discusses the concepts and science behind P indices. In the P index approach, best available scientific knowledge about field-scale processes is put together to produce one index score reflecting the potential for P movement to streams from a particular field. It takes into consideration both the source and the transport of P to yield a comprehensive assessment of the risk of P loss in runoff from the site. To date, at least 47 states have adopted the P index approach by modifying the basic components to fit local conditions. This adoption of the P index concept by at least 47 states illustrates the consensus among scientists, industry, and policy makers in the United States that such an integrated approach is appropriate ((Sharpley et al. 2003b).

Most P indices include a variety of data, such as soil test P, fertilization or manure/litter application rates, method and timing of application, soil erosion, and distance from field to stream. According to this SERA-17 position paper:

> ***If a source of P exists at a particular field (such as high soil test P, or recent fertilizer or manure applications), but there is no significant transport pathway for this P to leave the field and enter a stream, then the site does not represent a high risk for environmental P loss. Similarly, if there is a high risk of transport from a site (such as moderate runoff and/or erosion), but there is no large source of P at the site (i.e., low soil test P, or only small or no applications of fertilizer and /or manure), this site also will not represent a high risk for P loss. This is the basic concept of all P Indices, they identify two important categories***

They cautioned that when models are used in a regulatory capacity, because of the potential for model results to cause direct economic harm on individual producers, these:

> ***models should undergo additional validation and subsequent refinements prior to regulatory application.***

Plaintiffs' consultants did not conduct such validation exercises. In fact, measured values of P concentration in edge-of-field samples and stream samples at the hundreds of locations that Plaintiffs' consultants sampled in their field efforts for this case were never used to constrain or evaluate Dr. Engel's watershed modeling. Results of Dr. Engel's routing model application were only compared with stream water quality data collected at the bottom of the watershed, near Lake Tenkiller. See further discussion of this issue in the expert report prepared by Defendants' expert, Dr. Bierman. Dr. Engel applied a flawed approach when developing his model (Bierman 2009). Therefore, it would be possible for Dr. Engel to obtain a good fit between his modeled values and the measured values of TP at these downstream locations irrespective of whether his GLEAMS model estimates that he developed for the upper reaches of the watershed were correct, or were representative of the various potential sources of P across the landscape that Dr. Engel attempted to model.

22. *Plaintiffs' consultants provide no convincing evidence to indicate that land application of poultry litter is an important source of P and fecal indicator bacteria to streams in the IRW. To the best of my knowledge, Plaintiffs' consultants do not provide a single example of transport of P to stream water from land application of poultry litter in a comparable field setting and set of litter application guidelines under normal rainfall regimes, either within the IRW or anywhere else. Examples of small plot experimental treatments that involved artificial rainfall at intensities that seldom occur in the IRW (for example, Edwards et al. (1995), Daniel et al. (1995) are not representative of typical field conditions and therefore are of minimal relevance to water quality issues within the IRW. Such studies merely illustrate that, if it rains with a sufficient intensity (typically greater than or equal to 5 cm/hr [about 2 inches per hour]), it is possible to generate overland flow on some soils and therefore contribute P from soil to down-slope stream waters at those specific locations. Such studies have been valuable scientifically to improve understanding of P dynamics in simulated field settings, but they cannot be used to justify Plaintiffs' consultants' claims that under normal rainfall regimes in the IRW, an appreciable amount of P is transported in overland flow from litter-amended pastures to streams. First of all, it is quite possible that some overland flow might occur in certain areas, and subsequently that water may infiltrate into the soil lower on the hillslope, removing dissolved P from the water before the water reaches a stream. But most importantly, it simply does not rain in the IRW with such a high intensity on any except the rarest of occasions.*

Many of the datasets used for development of models and study of P transport mechanisms have been produced under artificial simulated rainfall (Edwards et al. 1995, Sauer et al. 2000, Kleinman et al. 2002, Radcliffe and Nelson 2005). However, the predictive relationships developed from simulated rainfall are not necessarily transferable to natural conditions. Radcliffe and Nelson (2005) concluded:

Because of the differences between P losses observed under simulated rainfall vs. natural rainfall, models should be validated with datasets derived from natural rainfall studies.

Published experimental studies that relied on simulated artificial rainfall to determine movement of P from fields amended with poultry litter typically applied artificial rain at intensity equal to 5 cm/hr or higher. Based on data from the National Climatic Data Center (Table 11-1), it seldom rains in the IRW with such intensity. Thus, results of these experimental studies are not directly applicable to questions regarding the extent to which P may move off pastures to which poultry litter had been land applied and into streams in the IRW.

I examined hourly precipitation data available for the IRW over the period from 1949 to 1997 for Tenkiller dam (at the bottom of the watershed) and from 1966 to 2008 for Fayetteville, Arkansas (at the top of the watershed). During only 0.05 % to 0.07% of the hours for which rainfall was recorded at these two monitoring stations (six individual hours at each station over a period of record of more than 40 years at each site) was the hourly rainfall intensity higher than 5 cm per hour (1.97 inches per hour). Only 0.1 percent of the hours for which rainfall was recorded exhibited hourly rain intensity higher than 1.7 inches per hour. On average, only during one hour out of every seven or eight years was the measured precipitation greater than 1.97 inches (2 cm). Thus, the publications cited by Plaintiffs' consultants, in support of their contention that P runs off pasture lands subsequent to land application of poultry litter, are not directly relevant to Plaintiffs' consultants' claims to the extent that these publications employed artificial experimental rain application at rates higher than commonly occur in the IRW.

Plaintiffs' consultants contend that one factor (land application of poultry litter) is the predominant cause of water quality impairment in the IRW. Plaintiffs' consultants offer no scientifically defensible evidence in support of that contention. Due to the large numbers of people and livestock (especially cattle) in the IRW, and as is indicated in the available data for the watershed and the body of scientific information on watershed sources of stream water pollution in general, it is clear that there are multiple sources of point and nonpoint contributions of P and fecal indicator bacteria to surface waters in the IRW. Plaintiffs' consultants offer no scientifically defensible evidence that land application of poultry litter is important in that regard. They certainly provide no scientifically defensible evidence that land application of poultry litter constitutes the dominant source. In contrast, stream water quality data collected by Plaintiffs' consultants for this case illustrate that P concentrations in stream waters in the IRW largely originate in and around urban areas and WWTP facilities.

With regard to potential bacterial contamination of water in the IRW, Defendants' expert Dr. Herbert DuPont concluded (2008, page 19) that Plaintiffs focused only on poultry as the potential source of environmental contamination, and that they made a non-scientific decision to pursue the poultry industry ignoring all other sources of contamination. Cattle are known to harbor and excrete into the environment bacterial pathogens that can cause human disease, including strains of pathogenic *E. coli*, *Cryptosporidium*, and *Salmonella*. Wildlife regularly add fecal indicator bacteria to stream water (Myoda 2008). Dr. DuPont reviewed studies indicating that the three most important sources of bacterial contamination of water in the United States are people, cattle, and wildlife. Plaintiffs' consultants ignored these, and assumed that human pathogens were present in the IRW even though they generally did not find them, and further that these pathogens that they did not find were contributed by poultry.

The primary approaches offered by Plaintiffs' consultants in their efforts to assign responsibility to the poultry industry for P that occurs in streams in the IRW are: 1) the edge-of-field water quality data, 2) Dr. Olsen's PCA analysis and 3) results of GLEAMS modeling by Dr. Engel. The edge-of-field data reveal nothing about specific sources of P beyond what Plaintiffs' consultants **assume**; similarly, edge-of-field data do not indicate that any of that water sampled at the edge-of-field (and at the edge of roads and along ditches) actually moved to any stream. As described more fully in other sections of this report, Dr. Olsen's PCA was not able to discriminate among the potential sources of P to stream waters in the non-urban portions of the watershed. The GLEAMS modeling relied on a totally empirical routing model to estimate the contribution of various potential sources to the upper end of Lake Tenkiller. As shown by Dr. Bierman (2008), varying model inputs can yield acceptable model estimates of P concentrations in stream water at the inlet to Lake Tenkiller. The model calibration demonstrated by Dr. Engel does not confirm that the parameters that he used in his model to apportion P sources are correct or even reasonable.

Radcliffe and Nelson (2005), in their position paper for SERA-17, summarized the group's position on watershed-scale modeling of P loading as follows:

> ***In our opinion, watershed-scale predictions of loadings to lakes are not reliable unless extensive, site-specific calibration is used. The same can be said for short-term (daily) predictions at the edge-of-field scale. These types of predictions remain in the research development stage. The capability to make predictions at this scale is, however, an appropriate long-term goal.***

As discussed by Dr. Bierman, in his expert report for this case (January, 2009), Plaintiffs' consultants did not provide site-specific calibration for their modeling effort anywhere except at the bottom of the watershed. As a result, they cannot scientifically defend the conclusions they draw from their model results with respect to sources of P within the watershed. Neither plaintiffs' edge-of-field data nor their stream data from sites scattered throughout the watershed were used to constrain their GLEAMS model calibration. Radcliffe and Nelson (2005, page 4) went on to say, in discussing the use of field-scale P loss model predictions to regulate individual farmers or producers, :

> ***caution must be used when models are applied for these expanded purposes. For example, because of the potential for model results to inflict direct economic harm on individual producers, models should undergo additional validation and subsequent refinements prior to regulatory application.***

The models applied by Plaintiffs' consultants in this case did not undergo such validation and refinement.

Dr. Harwood claims that she can identify the origin of fecal indicator bacteria that she finds in Lake Tenkiller (or elsewhere in the IRW) on the basis of the number of small pieces of bacterial DNA that she finds in the water. Her analyses **assume** that other bacteria (such as for example a fecal indicator like *E. coli* or potential pathogens like *Salmonella* or *Campylobacter*) will move along the same pathways (from source location through and over soils, through ground surface vegetation, and through stream systems, past potential predators and life-threatening conditions (sunlight, heat, drying, etc.) and finally arrive at her sample location) at the same rate and in the same proportion as her presumed *Brevibacterium avium*. There are many problems associated with having to make such assumptions. First, bacteria are different shapes and will therefore move through soil spaces at different rates. Second, bacteria are extremely small and the size of a single piece of bacterial DNA is much smaller than the entire bacterium from which it is extracted. For example, the length of *E. coli* is one-fortieth the width of the average human hair. The DNA of *E. coli* occupies only 1% of an *E. coli* bacterium (http://redpoll.pharmacy.ualberta.ca/CCDB/cgi-bin/STAT_NEW.cgi). One of the DNA segments that Dr. Harwood uses as a tracer is only a fraction of the length of the bacterial DNA. Thus it is obvious that Dr. Harwood is dealing with very tiny pieces of genetic material that cannot be assumed to move through the environment in the same way or at the same rate as living bacteria of that species or any other. Third, fecal indicator bacteria stick to soil surfaces, and this stickiness is partly a function of the properties of the outside of the bacterial cell surface. The surface of a living bacterium is not the same as the surface of a non-living piece of bacterial DNA. Dr. Harwood has not provided documentation that her tiny gene sequences move through the watershed to the same extent as do the living bacteria. Fourth, Dr. Harwood does not provide data to indicate how long her pieces of bacterial DNA persist in the environment. She made a general statement in her July 18, 2008 deposition (transcript page 12) that bacterial DNA may remain in the environment for a period of hours to several days. Living bacteria are capable of affecting humans only while they remain viable. Dr. Harwood provides no evidence that pieces of bacterial DNA can have any adverse effect on humans or any other species. In addition to these problems with respect to Dr. Harwood's assumptions about bacteria movement, it is also important to note that Dr. Harwood has not done any analyses that would shed light on the movement of P in the IRW.

Control of NPS water pollution requires first that one recognizes that there are multiple NPS sources. With that recognition, it is possible to implement a variety of BMPs that can effectively reduce the concentration of P and other constituents in stream water. This has been well demonstrated for one watershed within the IRW, as documented by Haraughty (1999). Oklahoma's first CWA Section 319(h) project was a demonstration of BMP effectiveness in the Battle Branch watershed over a three-year period. Public participation was high (84% of landowners). Installed BMPs included waste management plans, septic systems, dairy lagoons, poultry composters, waste storage structures, tree planting, and soil testing. About 80% of the P present was in the ortho-phosphate form (ortho-P). Ortho-P concentrations during baseflow events prior to BMP installation exhibited a mean of 0.067 mg/L. The mean baseflow ortho-P decreased to 0.024 mg/L after BMP installation. During storm flow conditions, the mean ortho-P decreased by more than an order of magnitude from 0.41 mg/L to 0.035 mg/L in response to installation of the BMPs (Haraughty 1999). It is noteworthy that these BMPs were not targeted in a punitive fashion to one industry, but rather resulted from voluntary adoption of a variety of practices among members of the entire community that resided within the watershed. Haraughty (1999, page 11) noted that, in the process of preparing the Comprehensive Basin Management Plan for the Oklahoma portion of the IRW,:

> ***Although some of these groups have specific interests in production activities within the basin, there was a noticeable lack of finger pointing. Each group recognized that the problems and causes were many and that contributions from all areas must be addressed.***

Q…Figure 16…Based on the plots, the regression lines that you've drawn for zinc, copper and arsenic as compared to phosphorus for these litter applied soil locations, isn't it true that there is no established relationship between phosphorus and these other chemicals, arsenic, copper and zinc, other than the simple fact that when phosphorus goes higher, the other chemicals go higher?

A. Okay. well, the graph shows that as phosphorus increases on these litter applied locations, that the concern – that the phos – well, the concentration of zinc, copper and arsenic increase, tend to increase.

Q. And that's all you can conclude from Figure 16; correct?

A. Well, since the only significant substantial source of phosphorus to these fields to my knowledge is poultry waste, then these materials are derived from poultry waste because it has substantial levels of phosphorus.

Again, it is Dr. Fisher's **assumption** that poultry litter is the dominant source that appears to be driving his interpretation of his data.

Dr. Fisher jumps, without basis, from the patterns shown in these graphs to his conclusion that concentrations of any of these parameters are derived from poultry waste. Similarly, on page 60, Dr. Fisher (2008b) states

As total P increases in Tenkiller sediments, total Cu, total Zn and total As also increase. This is consistent with these materials having the same concentrated source (i.e., poultry waste).

Dr. Fisher could have, but did not, go on to say that this pattern is also consistent with these materials having the same source (i.e., septic discharge, waste water plant effluent, cattle excrement, erosion, or urban runoff). He also could have said that this is consistent with these materials having different sources (i.e., some combination of the above NPS sources). The observed increases in the concentrations of P and various metals in Lake Tenkiller sediments could simply be due to the general increase in many or all sources of water pollution in this watershed during the latter half of the 20th Century. These data tell you little or nothing about the relative contribution of the various NPS sources.

In his conclusion 21, Dr. Fisher (2008b) states that

constituents of land disposed poultry waste run off fields… and are poorly attenuated.

He goes on to say that

if sufficient rainfall occurs in a short enough period of time, runoff is produced (i.e., not all of the water can be taken up by the soil and it runs off the field).

This last statement is of critical importance. As Dr. Fisher correctly states, runoff is produced when it rains hard enough that not all water can be taken up by the soil. What Dr. Fisher fails to state, however, is that it seldom rains with an intensity and duration sufficient to generate overland flow in most settings. As a consequence, there are certain limited portions of a given pasture that generate much of the overland flow during typical rainstorms. These are called the hydrologically active areas. They are also the portions of the pastures to which land owners are not allowed to apply poultry waste according to current regulations.

Dr. Fisher concluded that the population of poultry in the IRW has increased since at least 1950, that the amount of waste that they generate has increased, that there is a substantial amount of waste produced, that the waste is disposed near to where it is generated, and that it is mostly disposed of within the IRW. There is nothing about these conclusions that is unique to poultry. Exactly the same things can be said about people, cattle, and swine. Impacts of all sorts have increased in the IRW because the numbers of people, and their animals, have increased. Dr. Fisher's arguments that these increases in population numbers, and any associated effects, mainly concern poultry are without merit.

Dr. Fisher (2008b) goes on to suggest on page 62 that nutrients contained in beef cattle manure should be ignored in nutrient source estimates since a large proportion of these nutrients are obtained by the cattle from the forage and are recycled back to pastures. He ignores the fact that cattle also cycle (as opposed to recycle) nutrients from pasture and deposit them directly into the stream or to riparian areas adjacent to the stream from which they can be readily transported to the stream. There is no justification for removing cattle from the calculations based on the observation that they tend to consume forage grown within the watershed. Cattle are an effective agent of water pollution, in part, because they transport nutrients from forage into the stream or into a position from which they can be more readily moved into the stream when it rains. Construction of a watershed budget that ignores this fact is not pertinent to the questions at hand for determining the relative magnitude of potential NPS sources.

<u>Olsen</u>

Dr. Olsen's (2008) report is divided into an Introduction, four sections that present the methods and results of his field sampling program, and finally one section (Section 6) that evaluates sources of contamination in the IRW. My comments mainly pertain to Section 6. Dr. Olsen concludes that

> ***The chemical and bacterial contaminants of poultry waste are found in all the environmental fate and transport components throughout the IRW...***

He includes runoff water from fields, surface water, ground water, and springs in this characterization. But Dr. Olsen fails to state that the major constituent that he focuses on (P) is an important component of every potential source of both point and nonpoint source pollution in the IRW. Although P is found in poultry litter, it is also found in erosion (from stream banks, roads, heavily grazed areas, construction areas, parking lots, etc.), human waste (from waste water treatment plant outflows, septic system drainage, broken sewer lines, waste water spills and leaks, etc.), waste from other livestock (cattle, swine and horses), waste from wildlife, and runoff from urban and rural residential areas (for example, from pet waste and fertilizers). It is one of the most important nutrients for supporting virtually all forms of plant and animal life. Thus, the mere fact that P is found in various environmental compartments (e.g., edge-of-field, stream, lake, etc) of the IRW tells you nothing about the sources of that P or the relative magnitude of those sources. P is also expected to be found in these various environmental compartments in the absence of NPS pollution.

Dr. Olsen goes on to state that:

water acidification. Summarized and synthesized pertinent data and authored the State of Science and Technology Report for the National Acid Precipitation Assessment Program (NAPAP) on historical acidification.

- Served as project manager for a modeling project to assess aquatic and terrestrial effects of air pollutants throughout the southern Appalachian Mountains for the Southern Appalachian Mountain Initiative (SAMI).
- Served as lead author and individual responsible for synthesis and integration for report to the National Park Service on the sensitivity of natural resources in Shenandoah National Park to air pollution degradation.
- Coordinated research efforts of a team of experts in the fields of surface water chemistry, mathematical modeling, and paleoecology for the purpose of comparing paleoecological inferences and process-based model hindcasts of Adirondack Mountain lakewater chemistry. This project constitutes the most comprehensive, and only statistically-based, model validation exercise conducted to date for an acid-base chemistry watershed model. Supervised data analyses and interpretation, and served as lead author for final agency report.
- Directed field research project for the Alaska Department of Environmental Conservation on the Kenai Peninsula to investigate forest effects from industrial emissions of nitrogen. Coordinated and supervised all logistics and field sampling activities, including aerial infrared photography, measurements of forest growth and health, and collection of soil solution, conifer needles, precipitation, and throughfall. Directed data base construction, QA, data analyses, and interpretation; served as lead author on final report.
- Served as member of NAPAP's working group that prepared the aquatic portions of the 1990 Integrated Assessment (IA), NAPAP's final policy document for Congress. Drafted major portions of the IA; participated in a series of assessment meetings attended by federal, national laboratory and industry scientists, economists, and policy specialists; provided input on all aquatics sections of the final document. Also authored the aquatic sections of NAPAP's 1996 Report to Congress.
- Served as project manager for the Tillamook Bay National Estuary Project for several water quality monitoring projects to evaluate the concentrations and loads of nutrients, sediment, and fecal coliform bacteria in the five rivers that flow into Tillamook Bay, Oregon. These projects include long-term monitoring, storm monitoring, source area identification, and evaluation of the relationships between land use and water quality.
- Served as project manager for E&S's role in the construction and management of a diatom paleoclimate data cooperative for North and South America. The data cooperative brought together paleolimnological data from a multitude of sources that can be used to reconstruct aspects of historical regional climates from diatom remains in dated lake sediment cores.

AWARDS AND HONORS

Academic scholarship, Stonehill College, 1968-72
Massachusetts State Scholarship, 1969-72
Cum laude, Stonehill College, 1972

Postdoctoral fellowship, Royal Norwegian Council for Scientific and Industrial Research, 1984-86
Director's Technical Contribution Award, Corvallis Environmental Research Laboratory, U.S. EPA, 1987
Northrop Services, Inc., Best Orator, Effective Winning Presentations, 1987
Best Scientific Paper Award, Corvallis Environmental Research Laboratory, U.S. EPA, 1988

PUBLICATIONS

Books, Special Issues

Sullivan, T.J. 2005. Acidification - chronic. In: Lehr, J.H. and J. Keeley (Eds.). Water Encyclopedia: Surface and Agricultural Water. John Wiley & Sons.

Sullivan, T.J. 2000. Aquatic Effects of Acidic Deposition. Lewis Publ., Boca Raton, FL. 373 pp.

Seip, H.M., L. Pawlowski, and **T.J. Sullivan** (eds.). 1994. Environmental degradation due to heavy metals and acidifying deposition - A Polish-Scandinavian Workshop. Ecol. Engr. Special Issue. 3(3):205-314.

Pawlowski, L., H.M. Seip, and **T.J. Sullivan** (eds.). 1994. Aluminum in the environment. J. Ecol. Chem. 3(3).

Sullivan, T.J. and C. Moersch. 1993. Radon Alert (Teacher Guides for Junior High School Education). E&S Geographic and Information Services, Corvallis, OR. 2 vol., 204 pp.

Sullivan, T.J. and C. Moersch. 1992. Radon Alert (Teacher Guides for High School Education). E&S Geographic and Information Services, Corvallis, OR. 4 vol., 368 pp.

Sullivan, T.J. 1991. Oregon Coast Recreational Atlas. A Guide to Natural Resources and Recreational Opportunities. E&S Geographic and Information Services, Corvallis, OR. 106 pp.

NAPAP Aquatic Effects Working Group (Multiple authors including **Sullivan, T.J.**). 1991. National Acid Precipitation Assessment Program 1990 Integrated Assessment. National Acid Precipitation Assessment Program, Washington, DC. 520 pp.

Sullivan, T.J. 1990. Historical Changes in Surface Water Acid-Base Chemistry in Response to Acidic Deposition. State of the Science, SOS/T 11, National Acid Precipitation Assessment Program. 212 pp.

Journal Articles/Book Chapters

Sullivan, T.J., B.J. Cosby, B. Jackson, K.U. Snyder, and A.T. Herlihy. In review. Acidification and Prognosis for Future Recovery of Acid-Sensitive Streams in the Southern Blue Ridge Province.

Sullivan, T.J., B.J. Cosby, B. Jackson, and K.U. Snyder. In review. Critical Loads of Atmospheric Sulfur Deposition for the Protection and Recovery of Acid-Sensitive Streams in the Southern Blue Ridge Province.

Sullivan, T.J., B.J. Cosby, J.R. Webb, R.L. Dennis, A.J. Bulger, F.A. Deviney Jr. 2008. Streamwater acid-base chemistry and critical loads of atmospheric sulfur deposition in Shenandoah National Park, Virginia. Environ. Monit. Assess. 137:85-99. DOI 10:1007/s10661-007-9731-1

Zhai, J., C. T. Driscoll, **T. J. Sullivan**, and B. J. Cosby. 2008. Regional application of the PnET-BGC model to assess historical acidification of Adirondack lakes. Water Resour. Res., 44, W01421, doi:10.1029/2006WR005532.

McNeil, B.E., J.M. Read, **T.J. Sullivan**, T.C. McDonnell, I. J. Fernandez, and C.T. Driscoll. 2008. The spatial pattern of nitrogen cycling in the Adirondack Park, New York. Ecol. Appl. 18:438–452.

Sullivan, T.J., B.J. Cosby, A.T. Herlihy, C.T. Driscoll, I.J. Fernandez, T.C. McDonnell, C.W. Boylen, S.A. Nierzwicki-Bauer, and K.U. Snyder. 2007. Assessment of the extent to which intensively-studied lakes are representative of the Adirondack region and response to future changes in acidic deposition. Water Air Soil Pollut. 185:279-291.

Sullivan, T.J., J.R. Webb, K.U. Snyder, A.T. Herlihy, and B.J. Cosby. 2007. Spatial distribution of acid-sensitive and acid-impacted streams in relation to watershed features in the southern Appalachian Mountains. Water Air Soil Pollut. 182:57-71.

McNulty, S.G., E.C. Cohen, J.A. Moore Meyers, **T.J. Sullivan**, and H. Li. 2007. Estimates of critical acid loads and exceedances for forest soils across the conterminous United States. Environ. Poll. 149(3):281-292.

Sullivan, T.J., I.J. Fernandez, A.T. Herlihy, C.T. Driscoll, T.C. McDonnell, N.A. Nowicki, K.U. Snyder, and J.W. Sutherland. 2006. Acid-base characteristics of soils in the Adirondack Mountains, New York. Soil Sci. Soc. Amer. J. 70:141-152.

Sullivan, T.J., M. Wustenberg, K.U. Snyder, J. Moore, D. Moore, E. Gilbert, and E. Mallery. 2006. Relationship between size of vegetated buffers and transport of fecal coliform bacteria from pasturelands treated with dairy cow manure. Abstract. J. Dairy Sci. 89 (Suppl. 1): Abstract 298.

Sullivan, T.J., B.J. Cosby, K.A. Tonnessen, and D.W. Clow. 2005. Surface water acidification responses and critical loads of sulfur and nitrogen deposition in Loch Vale Watershed, Colorado. Water Resour. Res. 41:W01021, doi:10.1029/2004WR003414.

Sullivan, T.J., K. U. Snyder, E. Gilbert, J.M. Bischoff, M. Wustenberg, J. A. Moore, and D. Moore. 2005. Assessment of water quality in association with land use in the Tillamook Bay Watershed, Oregon. Water Air Soil Pollut. 161:3-23.

Sullivan, T.J., M.C. Saunders, B.L. Nash, K.A. Tonnessen, and B.J. Miller 2005. Application of a regionalized knowledge-based model for classifying the impacts of nitrogen, sulfur, and organic acids on lakewater chemistry. Knowledge Based Systems. 18(1):55-68.

Saunders, M.C., **T.J. Sullivan**, B.L. Nash, K.A. Tonnessen, and B.J. Miller. 2005. A knowledge-based approach for classifying lake water chemistry. Knowledge Based Systems. 18(1): 47-54.

Sullivan, T.J., B.J. Cosby, A.T. Herlihy, J.R. Webb, A.J. Bulger, K.U. Snyder, P.F. Brewer, E.H. Gilbert, and D.L. Moore. 2004. Regional model projections of future effects of sulfur and nitrogen deposition on streams in the southern Appalachian Mountains. Water Resour. Res. 40(2), W02101 doi:10.1029/2003WR001998.

Sullivan, T.J., M. Wustenberg, J. A. Moore, K. U. Snyder, E. Gilbert, D. Moore, and E. Mallery. 2004. Riparian plantings and fencing improve water quality in Tillamook River Watershed (Oregon). Ecolog. Restor. 22(2):138-140.

Sullivan, T.J., D.F. Charles, J.A. Bernert, B. McMartin, K.B. Vaché, and J. Zehr. 1999. Relationship between landscape characteristics, history, and lakewater acidification in the Adirondack Mountains, New York. Water Air Soil Pollut. 112:407-427.

Sullivan, T.J. and B.J. Cosby. 1998. Modeling the Concentration of Aluminum in Surface Waters. Water Air Soil Pollut. 105:643-659.

Sinha, R., M.J. Small, P.F. Ryan, **T.J. Sullivan**, and B.J. Cosby. 1998. Reduced-form modeling of surface water and soil chemistry for the Tracking and Analysis Framework. Water Air Soil Pollut. 105:617-642.

Sullivan, T.J. 1997. Ecosystem manipulation experimentation as a means of testing a biogeochemical model. Environ. Mgmt. 21(1):15-21.

Sullivan, T.J., J.M. Eilers, B.J. Cosby, and K.B. Vaché. 1997. Increasing role of nitrogen in the acidification of surface waters in the Adirondack Mountains, New York. Water Air Soil Pollut. 95:313-336.

Bernert, J.A., J.M. Eilers, **T.J. Sullivan**, K.E. Freemark, and C. Ribic. 1997. A quantitative method for delineating regions: an example for the Western Corn Belt Plains Ecoregion of the USA. Environ. Mgmt. 21:405-420.

Sullivan, T.J., B.J. Cosby, C.T. Driscoll, D.F. Charles, and H.F. Hemond. 1996. Influence of organic acids on model projections of lake acidification. Water Air Soil Pollut. 91:271-282.

Sullivan, T.J., B. McMartin, and D.F. Charles. 1996. Re-examination of the role of landscape change in the acidification of lakes in the Adirondack Mountains, New York. Sci. Total Environ. 183(3):231-248.

Sullivan, T.J. and B.J. Cosby. 1995. Testing, improvement, and confirmation of a watershed model of acid-base chemistry. Water Air Soil Pollut. 85:2607-2612.

Sullivan, T.J. 1994. Progress in quantifying the role of aluminum in acidification of surface waters. J. Ecol. Chem. 3:157-168.

Sullivan, T.J. 1994. Evaluation of biogeochemical models using data from experimental ecosystem manipulations. In Jenkins, A., R.C. Ferrier, and C. Kirby. Ecosystem

Manipulation Experiments: Scientific Approaches, Experimental Design, and Relevant Results. Ecosystems Research Report No. 20. ECSC-EC-EAEC, Brussels. pp. 344-352.

Sullivan, T.J., B.J. Cosby, S.A. Norton, D.F. Charles, R.F. Wright, and E. Gjessing. 1994. Multi-site testing and evaluations of a geochemical model of acid-base chemistry: confirmation of the MAGIC model using catchment manipulation experiments and historical diatom inferences. In Jenkins, A., R.C. Ferrier, and C. Kirby. Ecosystem Manipulation Experiments: Scientific Approaches, Experimental Design, and Relevant Results. Ecosystems Research Report No. 20. ECSC-EC-EAEC, Brussels. pp. 360-365.

Driscoll, C.T., M.D. Lehtinen, and **T.J. Sullivan**. 1994. Modeling the acid-base chemistry of organic solutes in Adirondack, New York, lakes. Water Resour. Res. 30:297-306.

Sullivan, T.J. and D.F. Charles. 1994. The feasibility and utility of a paleolimnology/ paleoclimate data cooperative for North America. J. Paleolimnol. 10:265-273.

Sullivan, T.J. 1993. Whole ecosystem nitrogen effects research in Europe. Environ. Sci. Technol. 27(8):1482-1486.

Sullivan, T.J., R.S. Turner, D.F. Charles, B.F. Cumming, J.P. Smol, C.L. Schofield, C.T. Driscoll, B.J. Cosby, H.J.B. Birks, A.J. Uutala, J.C. Kingston, S.S. Dixit, J.A. Bernert, P.F. Ryan, and D.R. Marmorek. 1992. Use of historical assessment for evaluation of process-based model projections of future environmental change: Lake acidification in the Adirondack Mountains, New York, U.S.A. Environ. Poll. 77:253-262.

Turner, R.S., P.F. Ryan, D.R. Marmorek, K.W. Thornton, **T.J. Sullivan**, J.P. Baker, S.W. Christensen, and M.J. Sale. 1992. Sensitivity to change for low-ANC eastern US lakes and streams and brook trout populations under alternative sulfate deposition scenarios. Environ. Poll. 77:269-277.

Sullivan, T.J. 1991. Long-term temporal trends in surface water chemistry. pp. 615-639. In: Charles, D.F. (Ed.), Acid Deposition and Aquatic Ecosystems: Regional Case Studies, Springer-Verlag, New York.

Husar, R.B., **T.J. Sullivan**, and D.F. Charles. 1991. Methods for evaluation of historical change. pp. 65-82. In: Charles, D.F. (Ed.), Acid Deposition and Aquatic Ecosystems: Regional Case Studies, Springer-Verlag, New York.

Eilers, J.M., **T.J. Sullivan**, and K.C. Hurley. 1990. The most dilute lake in the world? Hydrobiologia 199:1-6.

Sullivan, T.J., D.F. Charles, J.P. Smol, B.F. Cumming, A.R. Selle, D.R. Thomas, J.A. Bernert, and S.S. Dixit. 1990. Quantification of changes in lakewater chemistry in response to acidic deposition. Nature 345:54-58.

Sullivan, T.J., D.L. Kugler, M.J. Small, C.B. Johnson, D.H. Landers, B.J. Rosenbaum, W.S. Overton, W.A. Kretser, and J. Gallagher. 1990. Variation in Adirondack, New York, lakewater chemistry as a function of surface area. Water Resour. Bull. 26:167-176.

Seip, H.M., D.O. Anderson, N. Christophersen, **T.J. Sullivan**, and R.D. Vogt. 1989. Variations in concentrations of aqueous aluminum and other chemical species during hydrological episodes at Birkenes, southernmost Norway. J. Hydrol. 108:387-405.

Johnson, C.B., **T.J. Sullivan**, and D.J. Blick. 1989. Defining regional populations of lakes for the assessment of surface water quality. Water Resour. Bull. 25:1-8.

Seip, H.M., N. Christophersen, and **T.J. Sullivan**. 1989. Episodic variations in streamwater aluminum chemistry at Birkenes, southernmost Norway. pp. 159-169. In: Lewis, T.E. (Ed.), Environmental Chemistry and Toxicology of Aluminum, Lewis Publishers Inc., Chelsea, MI.

Sullivan, T.J., C.T. Driscoll, S.A. Gherini, R.K. Munson, R.B. Cook, D.F. Charles, and C.P. Yatsko. 1989. The influence of organic acid anions and aqueous aluminum on measurements of acid neutralizing capacity in surface waters. Nature 338:408-410.

Sullivan, T.J., J.M. Eilers, M.R. Church, D.J. Blick, K.N. Eshleman, D.H. Landers, and M.S. DeHaan. 1988. Atmospheric wet sulfate deposition and lakewater chemistry. Nature 331:607-609.

Sullivan, T.J., C.T. Driscoll, J.M. Eilers, and D.H. Landers. 1988. Evaluation of the role of sea salt inputs in the long-term acidification of coastal New England lakes. Environ. Sci. Technol. 22:185-190.

Muniz, I.P., R. Andersen, and **T.J. Sullivan**. 1987. Physiological response of brown trout spawners and post-spawners to acidic streamwater. Water Air Soil Pollut. 36:371-379.

Seip, H.M., N. Christophersen, and **T.J. Sullivan**. 1987. Episodic variations in streamwater aluminum chemistry at Birkenes, southernmost Norway. Preprint extended abstract. Amer. Chem. Soc. Meeting, New Orleans, August 30-Sept. 4.

Andersen, R., Ø. Haraldstad, I.P. Muniz, and **T.J. Sullivan**. 1987. Effects of shellsand on water quality and mature brown trout. Fauna 40:150-159 (in Norwegian).

Sullivan, T.J., I.P. Muniz, and H.M. Seip. 1986. A comparison of frequently used methods for the determination of aqueous aluminum. Int. J. Environ. Anal. Chem. 26:61-75.

Sullivan, T.J., N. Christophersen, I.P. Muniz, H.M. Seip and P.D. Sullivan. 1986. Aqueous aluminum chemistry response to episodic increases in discharge. Nature 323:324-327.

Røyset, O. and **T.J. Sullivan**. 1986. Effect of dissolved humic compounds on the determination of aqueous aluminum by three spectrophotometric methods. Int. J. Environ. Anal. Chem. 27:305-14.

Sullivan, T.J. and M.C. Mix. 1985. Persistence and fate of polynuclear aromatic hydrocarbons deposited on slash burn sites in the Cascade Mountains and Coast Range of Oregon. Arch. Environ. Contam. Toxicol. 14:187-192.

Sullivan, T.J. and M.C. Mix. 1983. Pyrolytic deposition of polynuclear aromatic hydrocarbons due to slash burning on clear-cut sites. Bull. Environ. Contam. Toxicol. 31:207-215.

Sullivan, T.J. and M.C. Mix. 1983. A simple and inexpensive method for measuring integrated light energy. Environ. Sci. Technol. 17:127-128.

Sullivan, T.J. 1982. Avian species diversity: Its relation to the competition hypothesis. Proc. Oregon Acad. Sci. 18:10-20

Sullivan, T.J. 1977. Avian and mammalian distribution in the Powderhorn Primitive Area, Colorado. M.A. thesis. Western State College, Gunnison, CO. 209 pp.

Reports

Sullivan, T.J., B.J. Cosby, K.U. Snyder, A.T. Herlihy, B. Jackson. 2007. Model-Based Assessment of the Effects of Acidic Deposition on Sensitive Watershed Resources in the National Forests of North Carolina, Tennessee, and South Carolina. Final report prepared for USDA Forest Service, Asheville, NC. E&S Environmental Chemistry, Inc., Corvallis, OR.

Sullivan, T.J., A.T. Herlihy. 2007. Air Quality Related Values and Development of Associated Protocols for Evaluation of the Effects of Atmospheric Deposition on Aquatic and Terrestrial Resources on Forest Service Lands. Final report prepared for the U.S.D.A Forest Service.

Sullivan, T.J. 2007. What's up with the Air? Shenandoah National Park. National Park Service, Luray, VA.

Sullivan, T.J., C.T. Driscoll, B.J. Cosby, I.J. Fernandez, A.T. Herlihy, J. Zhai, R. Stemberger, K.U. Snyder, J.W. Sutherland, S.A. Nierzwicki-Bauer, C.W. Boylen, T.C. McDonnell, and N.A. Nowicki. 2006. Assessment of the Extent to Which Intensively-Studied Lakes are Representative of the Adirondack Mountain Region. Final Report 06-17. New York State Energy Research and Development Authority, Albany, NY.

Snyder, K., **T. Sullivan**, D. Moore, and R. Raymond. 2006. Lower Umpqua River Watershed Assessment. Prepared for the Umpqua Basin Watershed Council. E&S Environmental Chemistry, Inc., Corvallis, OR.

Snyder, K., **T. Sullivan**, D. Moore, and R. Raymond. 2006. Mill Creek Watershed Assessment. Prepared for the Umpqua Basin Watershed Council. E&S Environmental Chemistry, Inc., Corvallis, OR.

Snyder, K., **T. Sullivan**, D. Moore, and R. Raymond. 2006. Middle Umpqua River Watershed Assessment. Prepared for the Umpqua Basin Watershed Council. E&S Environmental Chemistry, Inc., Corvallis, OR.

Snyder, K., **T. Sullivan**, D. Moore, and R. Raymond. 2006. Upper Umpqua River Watershed Assessment. Prepared for the Umpqua Basin Watershed Council. E&S Environmental Chemistry, Inc., Corvallis, OR.

Sullivan, T.J. and B.J. Cosby. 2004. Aquatic critical load development for the Monongahela National Forest, West Virginia. Report Prepared for USDA Forest Service, Monongahela National Forest, Elkins, WV. E&S Environmental Chemistry, Inc., Corvallis, OR.

Webb, J.R., **T.J. Sullivan**, and B. Jackson. 2004. Assessment of Atmospheric Deposition Effects on National Forests. Protocols for Collection of Supplemental Stream Water and Soil Composition Data for the MAGIC Model. Report prepared for USDA Forest Service, Asheville, NC. E&S Environmental Chemistry, Inc., Corvallis, OR.

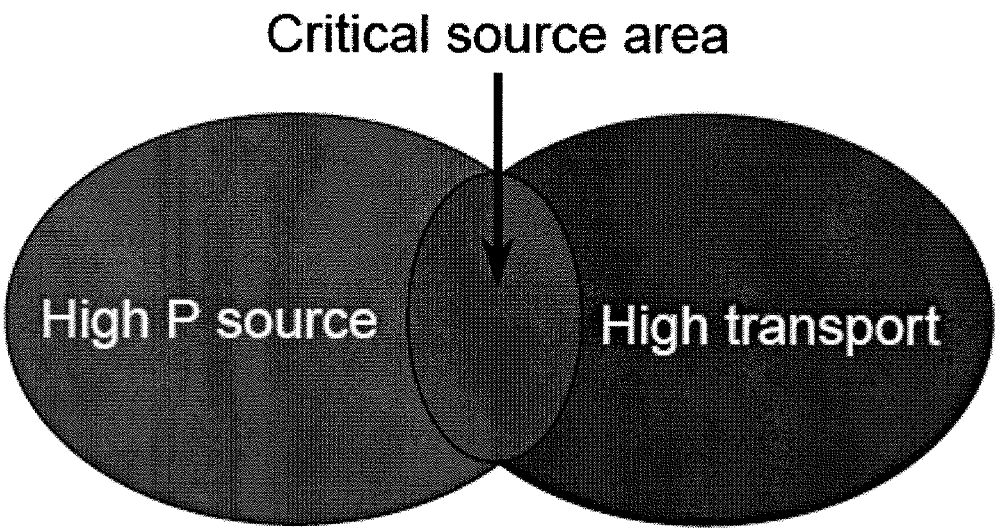

Figure 11-2. Schematic representation of critical source areas, the intersection of the locations where both a P source occurs and there is opportunity for transport of some of that P to a stream. (Taken from Sharpley et al. 2003a)

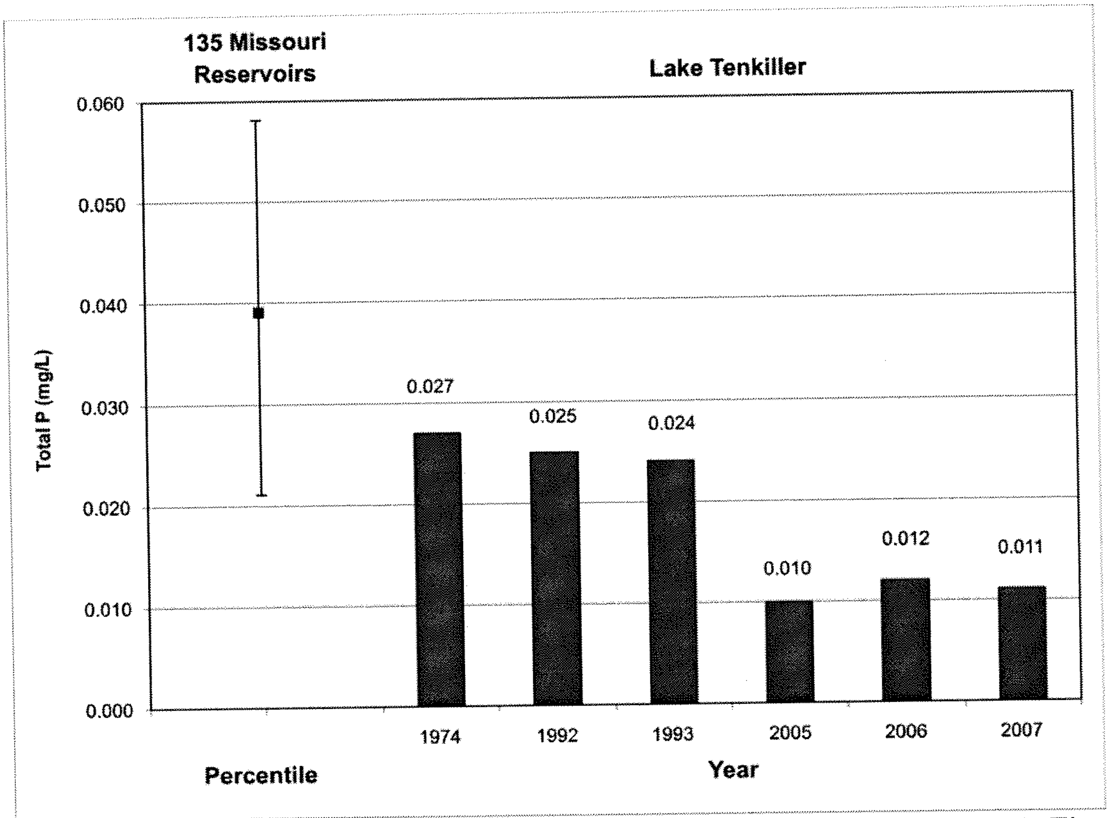

Figure 15-3. Total P concentrations reported by Cooke and Welch (2008, their Figure 7) at site LK-01 (the lacustrine site nearest the Lake Tenkiller dam) in 1974, 1992, 1993, and 2005 through 2007. Also shown for comparison are the median and quartile values for total P measured in 135 reservoirs located throughout Missouri (based on data published by Jones et al. 2004). Phosphorus concentrations in recent years place Lake Tenkiller in the mesotrophic class and show a dramatic decrease (by more than 50%) in the total P concentration compared with earlier years.

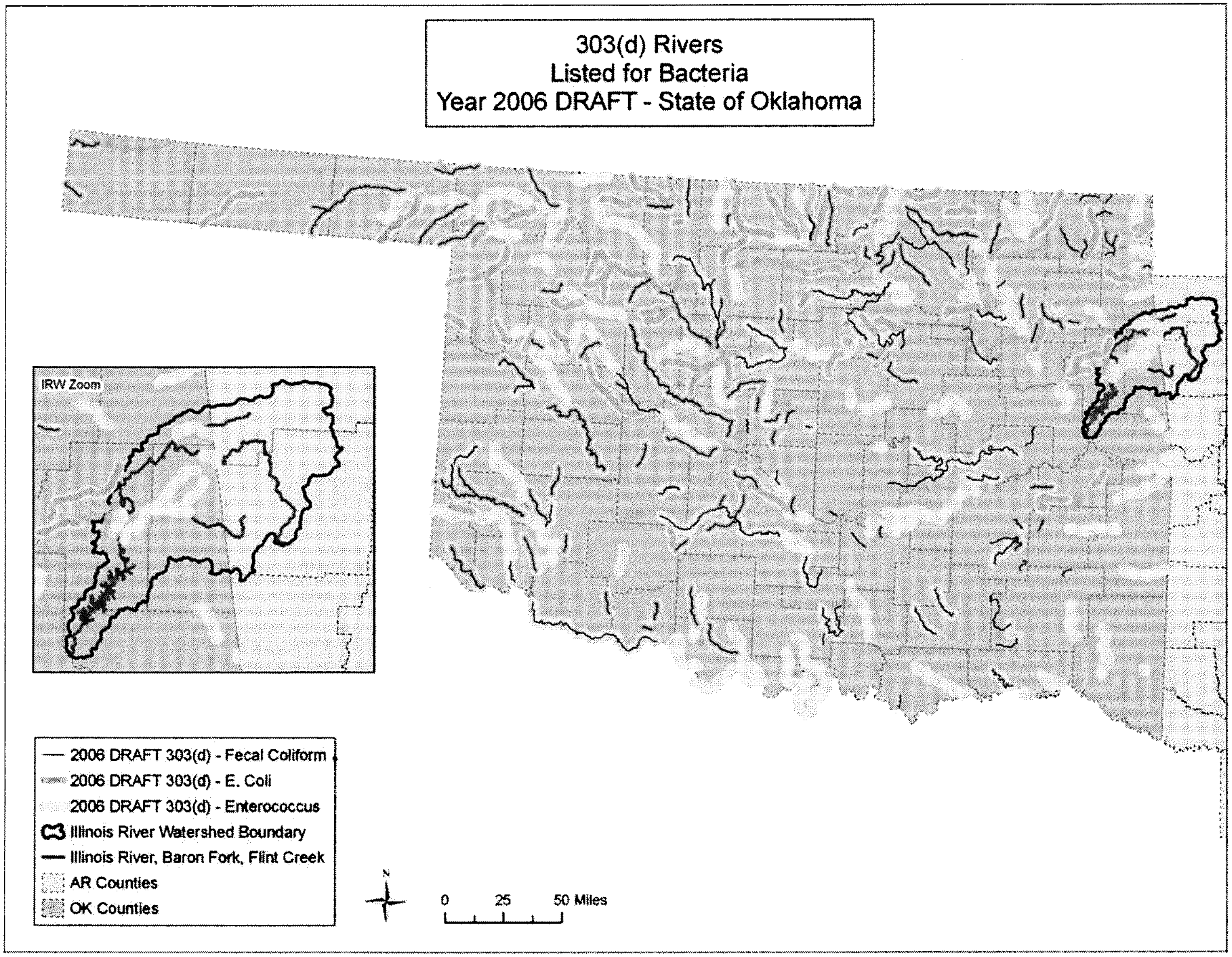

Figure 2-4. **Streams within Oklahoma that are 303(d) listed for bacteria, based on the 2006 303(d) list. Listings are shown separately for fecal coliform bacteria, *E. coli*, and enterococcus. Listings are widespread throughout the state. The spatial data for 2008 303(d) listings were not available at the time this map was produced. (Source: Oklahoma Department of Environmental Quality)**

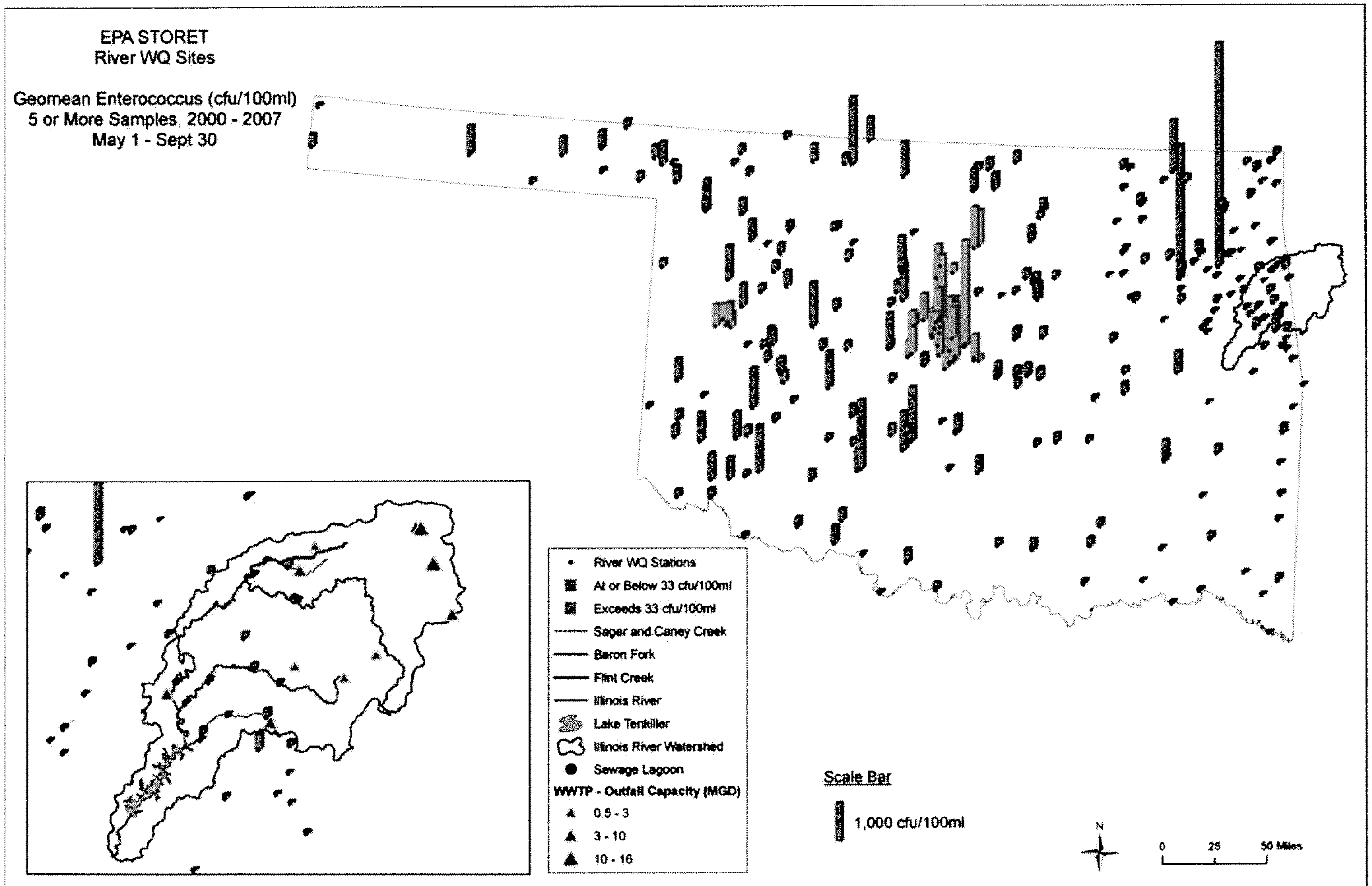

Figure 2-6. **Map showing the geomean of enterococcus bacteria concentrations measured at all sites in Oklahoma represented in EPA's STORET database by five or more samples during the recreational period (May 1 to September 30) during the years 2000 through 2007. The height of each bar is proportional to the geomean bacteria concentration. Dots at the base of each bar show the locations of sample collection. The boundaries of the IRW are shown in eastern Oklahoma and northwestern Arkansas. Samples that exceed the primary contact geomean standard are shown in orange; those that do not exceed the standard are shown in green.**

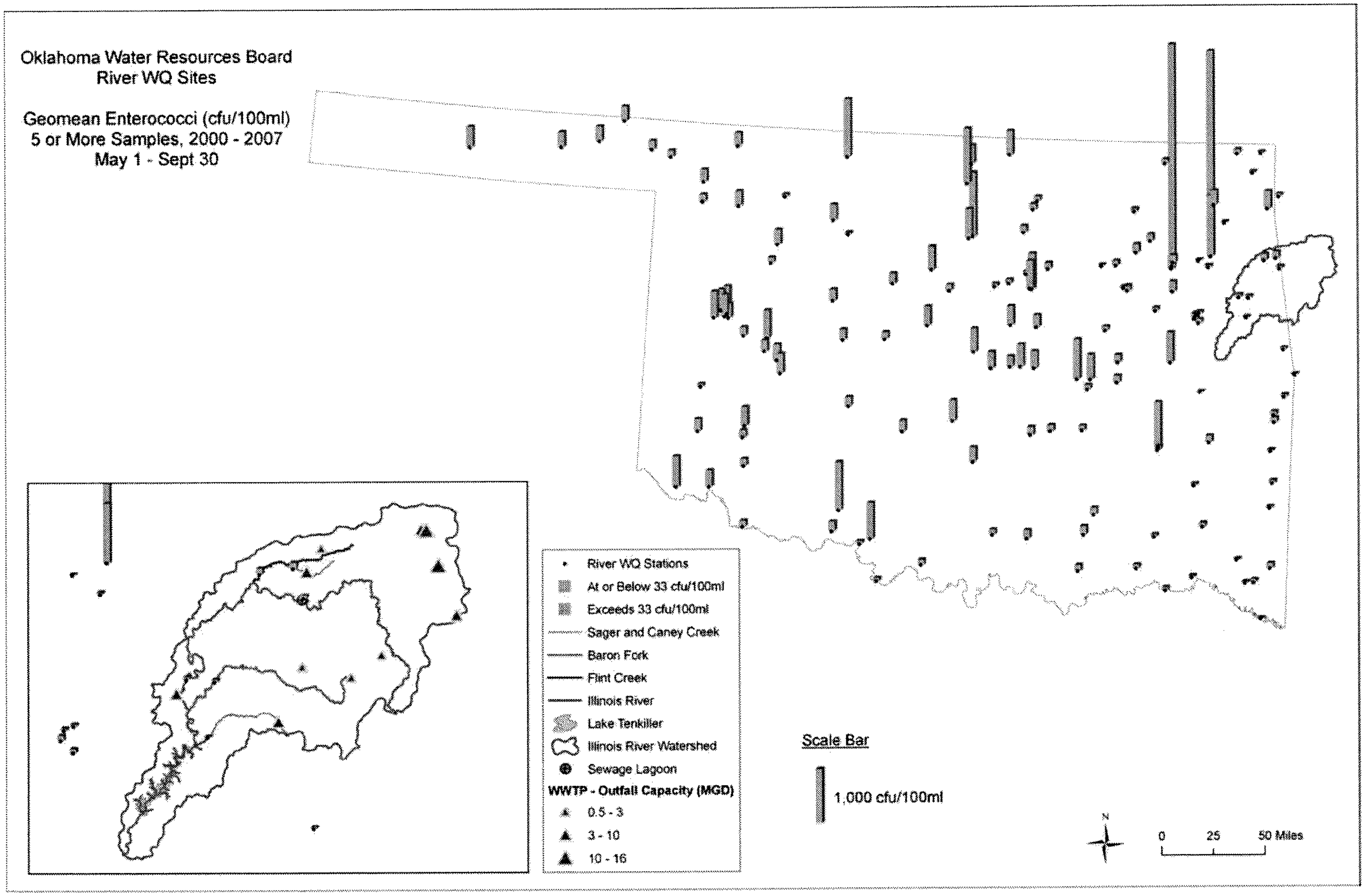

Figure 2-7. Map showing the geomean of enterococcus bacteria concentrations measured at all sites in Oklahoma represented in OWRB's database by five or more samples during the recreational period (May 1 to September 30) during the years 2000 through 2007. The height of each bar is proportional to the geomean bacteria concentration. Dots at the base of each bar show the locations of sample collection. The boundaries of the IRW are shown in eastern Oklahoma and northwestern Arkansas. Samples that exceed the primary contact geomean standard are shown in orange; those that do not exceed the standard are shown in green.

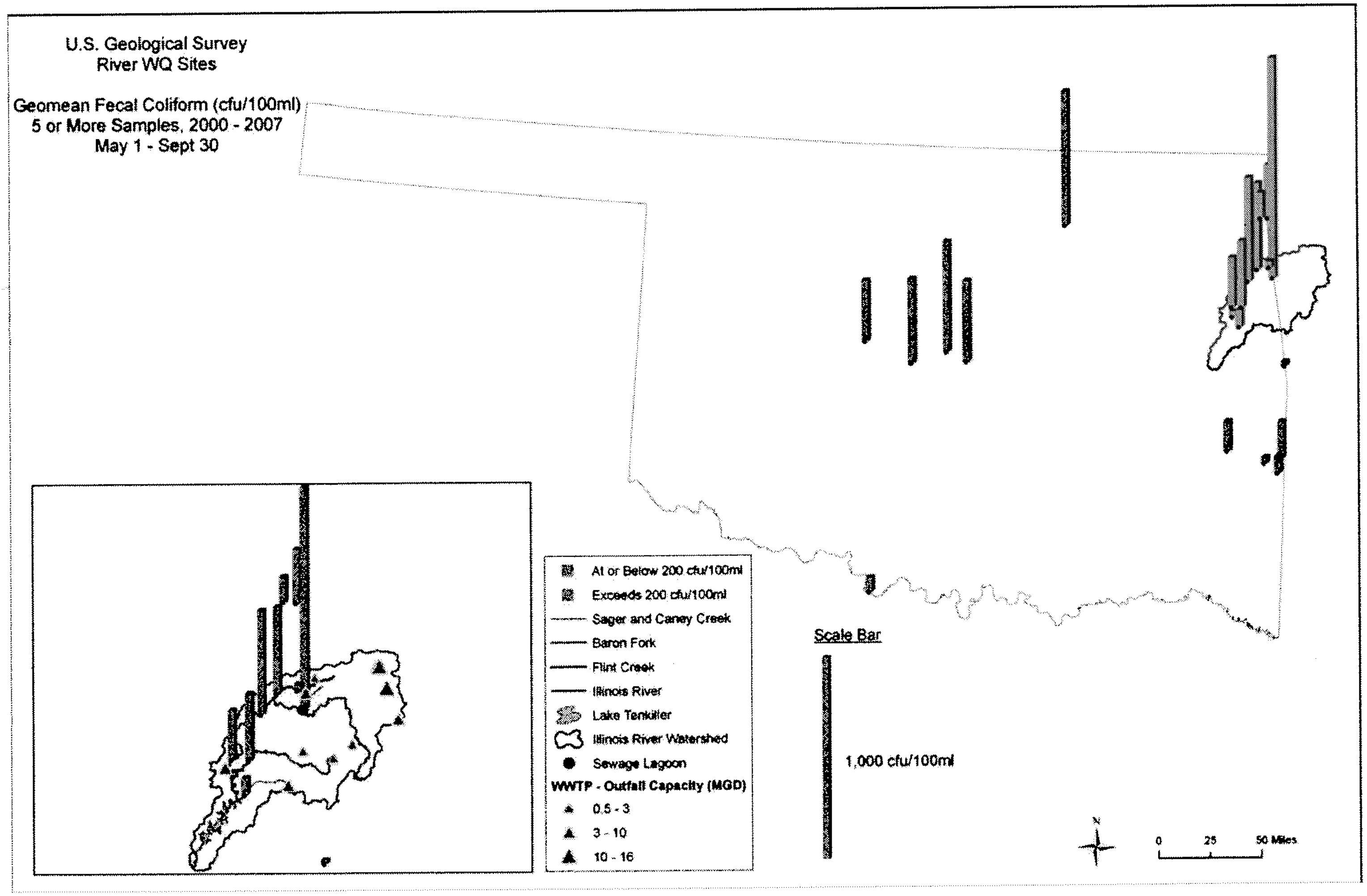

Figure 2-8. **Map showing the geomean of fecal coliform bacteria concentrations measured at all sites in Oklahoma represented in USGS's database by five or more samples during the recreational period (May 1 to September 30) during the years 2000 through 2007. The height of each bar is proportional to the geomean bacteria concentration. Dots at the base of each bar show the locations of sample collection. The boundaries of the IRW are shown in eastern Oklahoma and northwestern Arkansas. Samples that exceed the primary contact geomean standard are shown in orange; those that do not exceed the standard are shown in green. Note that because relatively few sites within Oklahoma were sampled by USGS, these data are not particularly helpful on their own in evaluating statewide patterns.**

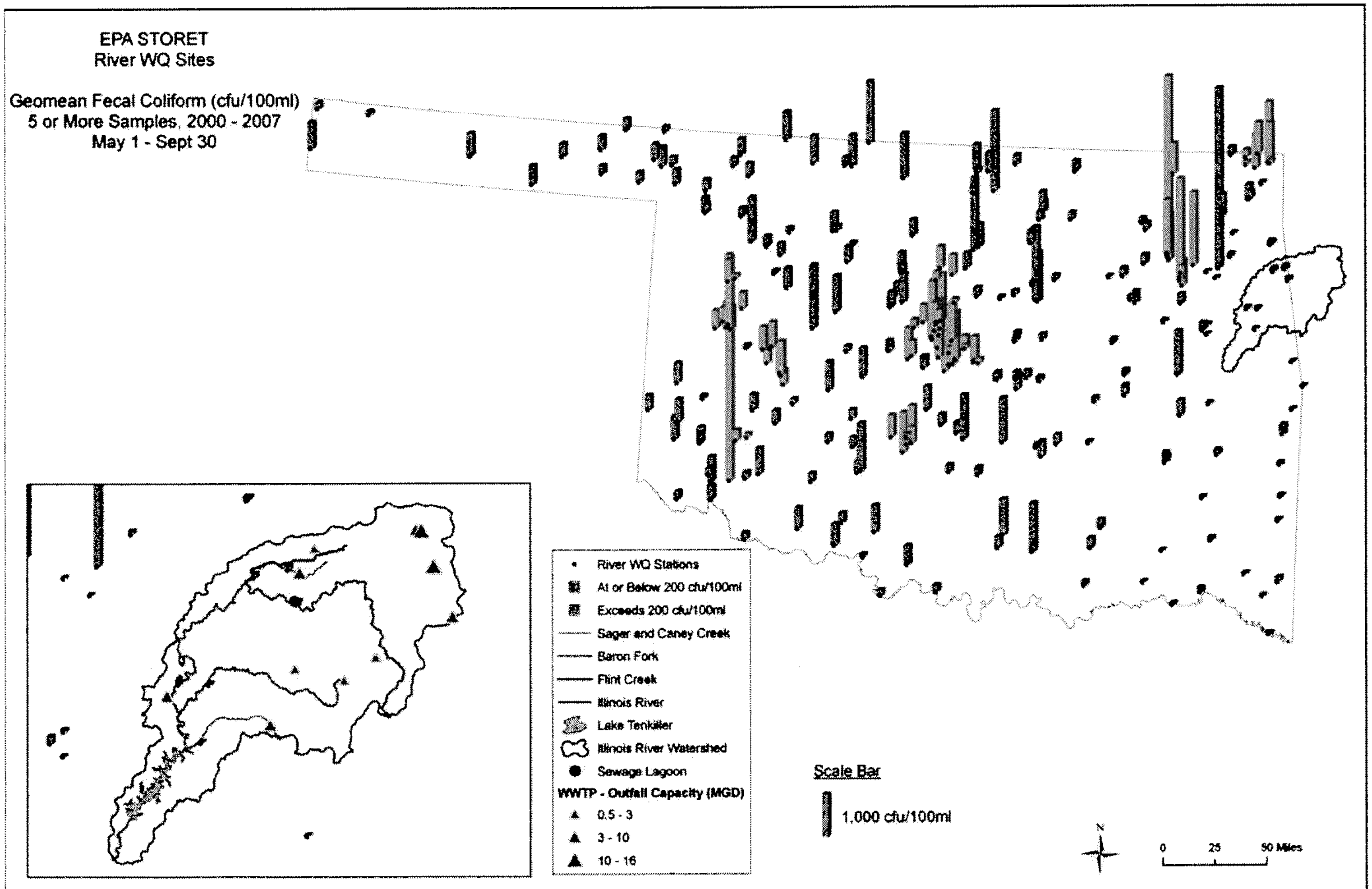

Figure 2-9. Map showing the geomean of fecal coliform bacteria concentrations measured at all sites in Oklahoma represented in EPA's STORET database by five or more samples during the recreational period (May 1 to September 30) during the years 2000 through 2007. The height of each bar is proportional to the geomean bacteria concentration. Dots at the base of each bar show the locations of sample collection. The boundaries of the IRW are shown in eastern Oklahoma and northwestern Arkansas. Samples that exceed the primary contact geomean standard are shown in orange; those that do not exceed the standard are shown in green.

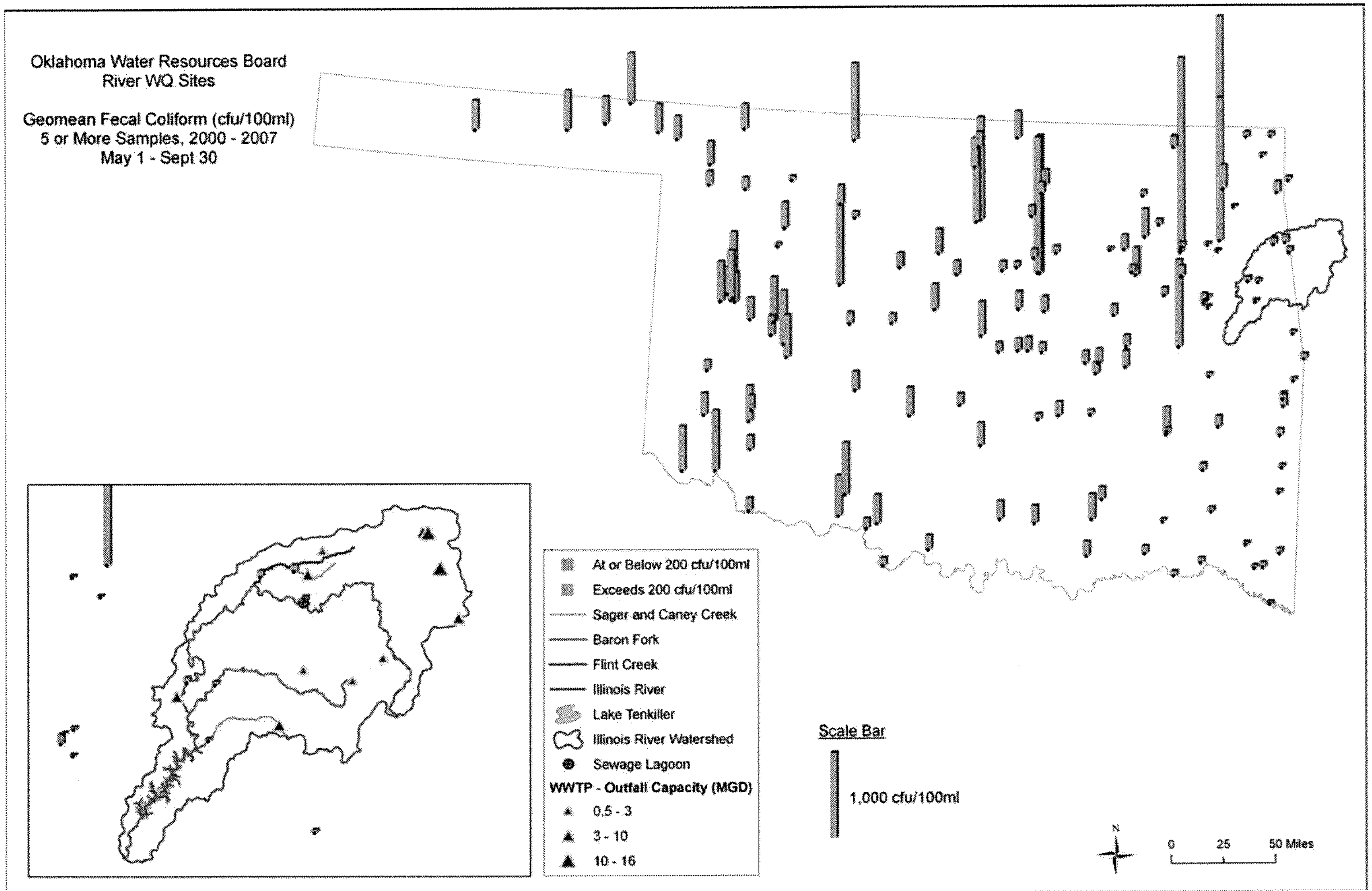

Figure 2-10. Map showing the geomean of fecal coliform bacteria concentrations measured at all sites in Oklahoma represented in OWRB's database by five or more samples during the recreational period (May 1 to September 30) during the years 2000 through 2007. The height of each bar is proportional to the geomean bacteria concentration. Dots at the base of each bar show the locations of sample collection. The boundaries of the IRW are shown in eastern Oklahoma and northwestern Arkansas. Samples that exceed the primary contact geomean standard are shown in orange; those that do not exceed the standard are shown in green.

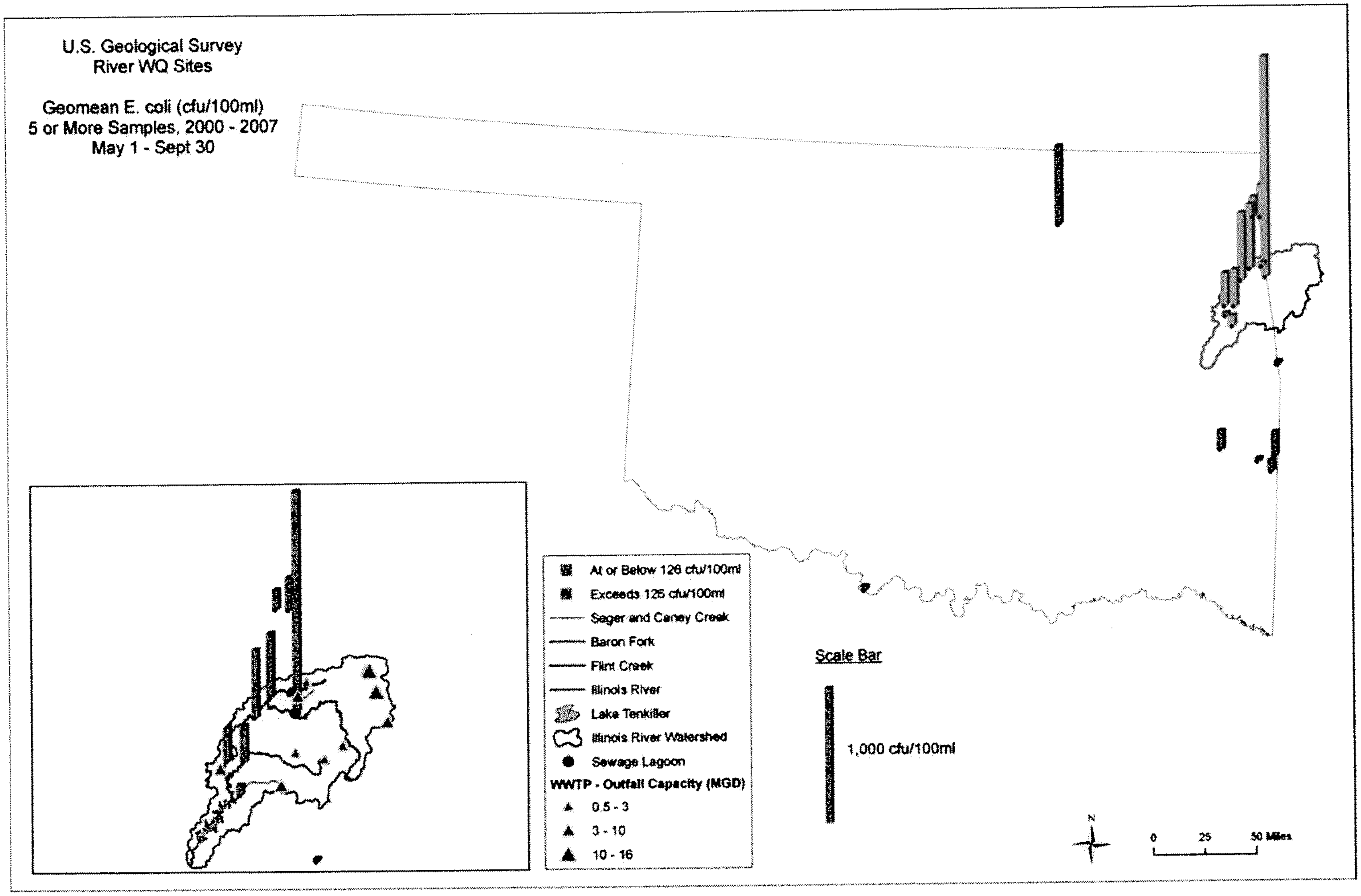

Figure 2-11. Map showing the geomean of *E. coli* concentrations measured at all sites in Oklahoma represented in USGS's database by five or more samples during the recreational period (May 1 to September 30) during the years 2000 through 2007. The height of each bar is proportional to the geomean bacteria concentration. Dots at the base of each bar show the locations of sample collection. The boundaries of the IRW are shown in eastern Oklahoma and northwestern Arkansas. Samples that exceed the primary contact geomean standard are shown in orange; those that do not exceed the standard are shown in green. Note that because relatively few sites within Oklahoma were sampled by USGS, these data are not particularly helpful on their own in evaluating statewide patterns.

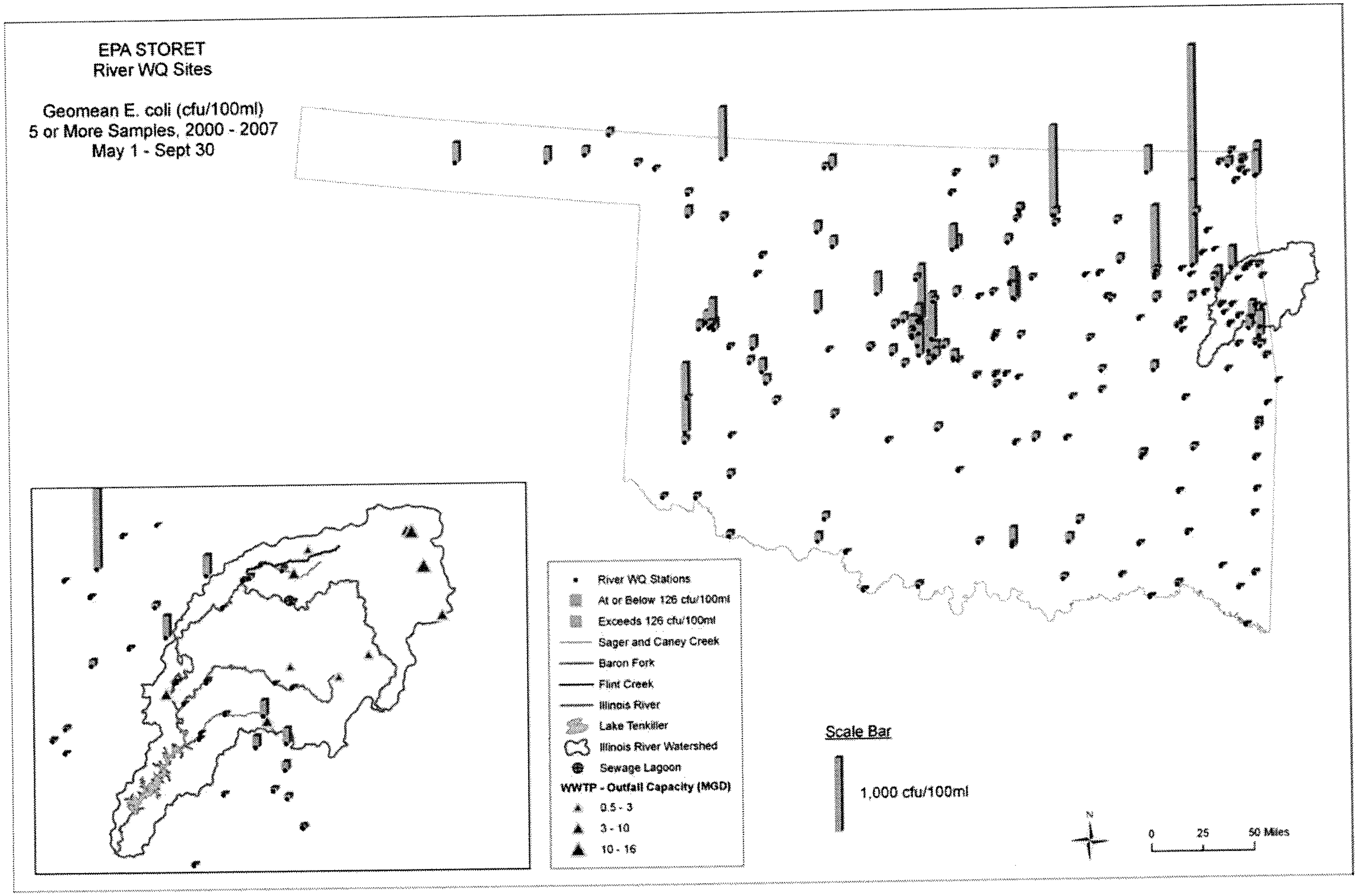

Figure 2-12. Map showing the geomean of *E. coli* concentrations measured at all sites in Oklahoma represented in EPA's STORET database by five or more samples during the recreational period (May 1 to September 30) during the years 2000 through 2007. The height of each bar is proportional to the geomean bacteria concentration. Dots at the base of each bar show the locations of sample collection. The boundaries of the IRW are shown in eastern Oklahoma and northwestern Arkansas. Samples that exceed the primary contact geomean standard are shown in orange; those that do not exceed the standard are shown in green.

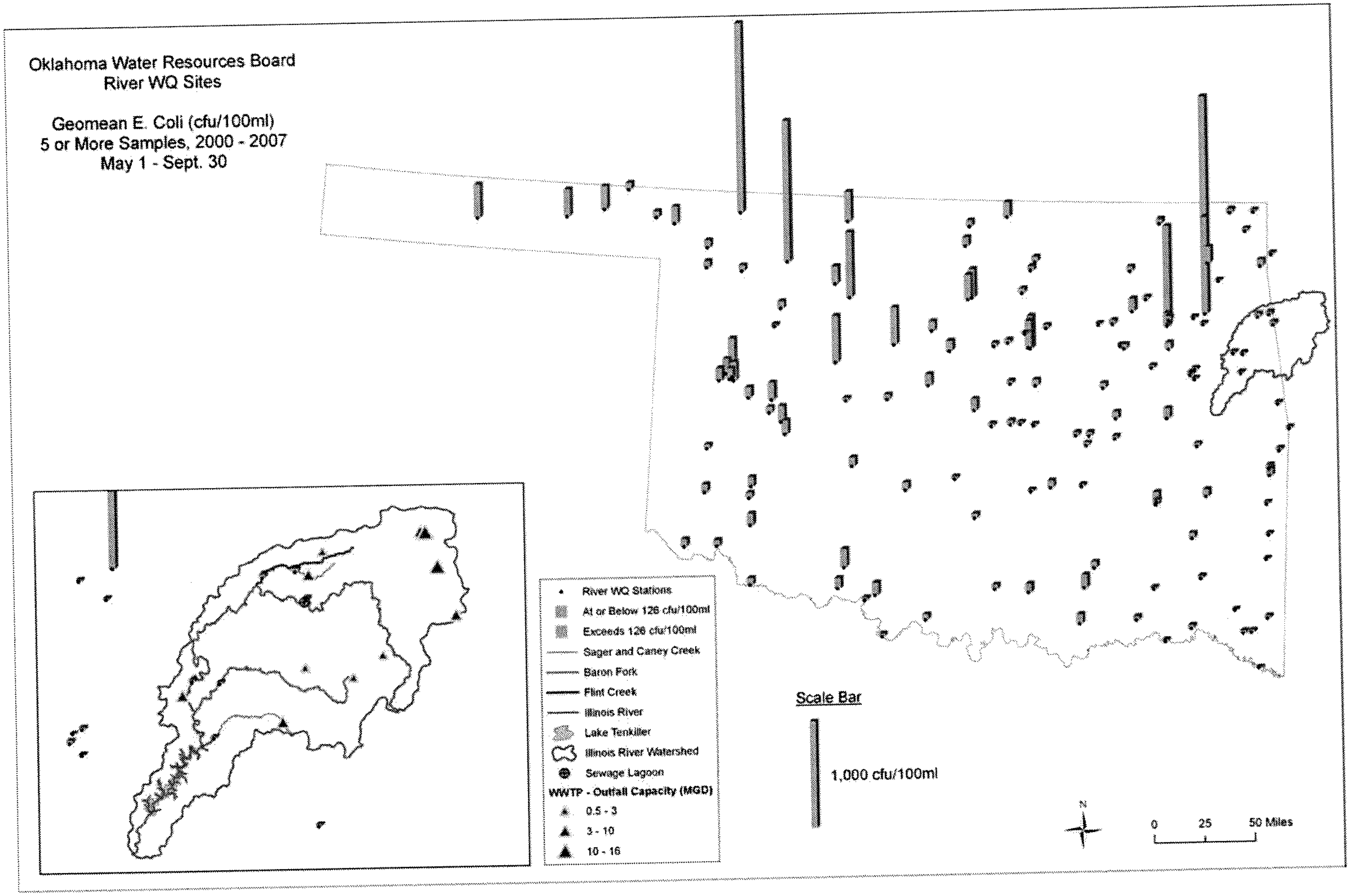

Figure 2-13. Map showing the geomean of *E. coli* concentrations measured at all sites in Oklahoma represented in OWRB's database by five or more samples during the recreational period (May 1 to September 30) during the years 2000 through 2007. The height of each bar is proportional to the geomean bacteria concentration. Dots at the base of each bar show the locations of sample collection. The boundaries of the IRW are shown in eastern Oklahoma and northwestern Arkansas. Samples that exceed the primary contact geomean standard are shown in orange; those that do not exceed the standard are shown in green.

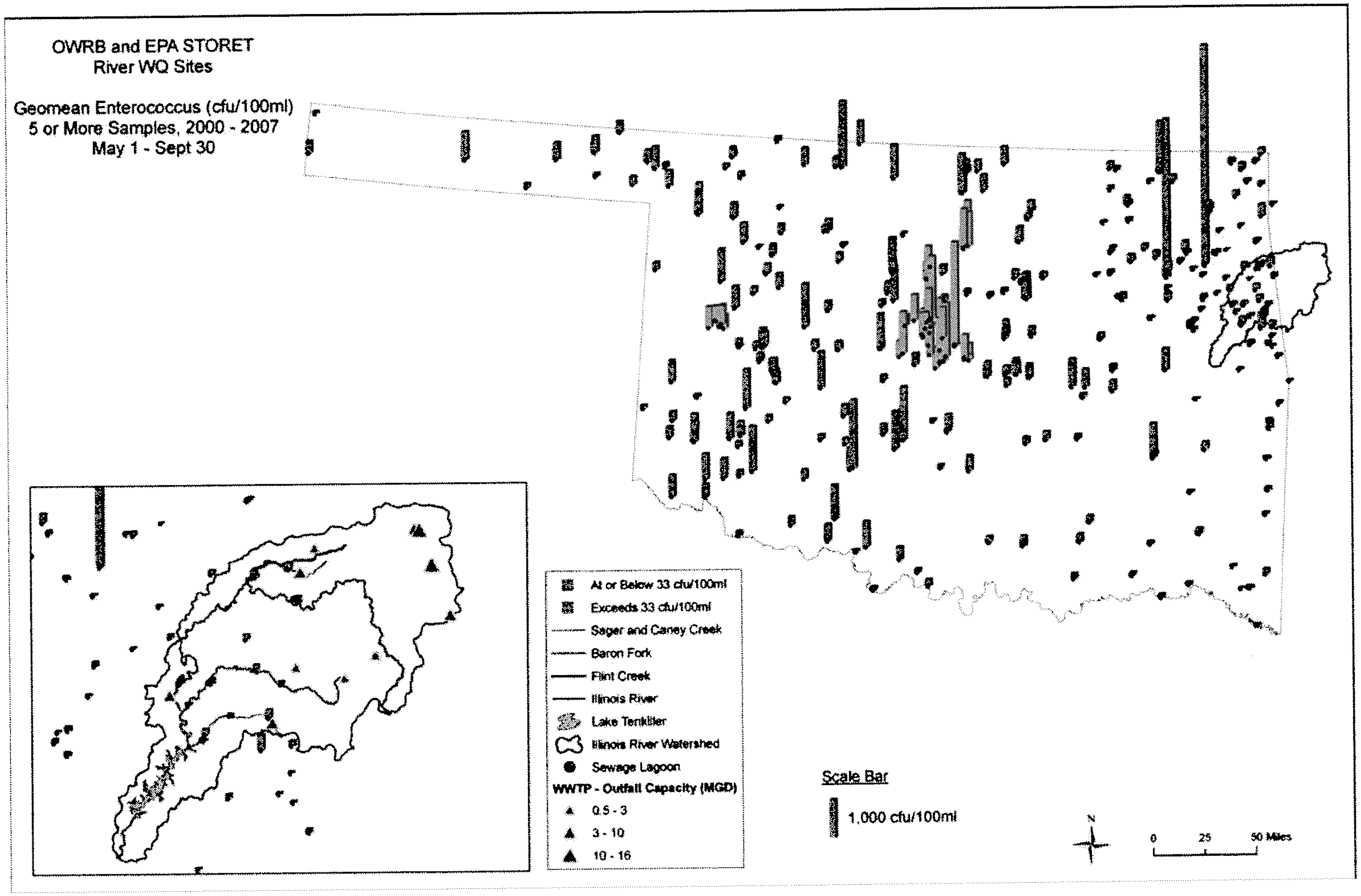

Figure 2-15. Map showing the geomean of enterococcus concentrations measured at all sites in Oklahoma represented in OWRB's and EPA's STORET databases by five or more samples during the recreational period (May 1 to September 30) during the years 2000 through 2007. The height of each bar is proportional to the geomean bacteria concentration. Dots at the base of each bar show the locations of sample collection. The boundaries of the IRW are shown in eastern Oklahoma and northwestern Arkansas. Samples that exceed the primary contact geomean standard are shown in orange; those that do not exceed the standard are shown in green.

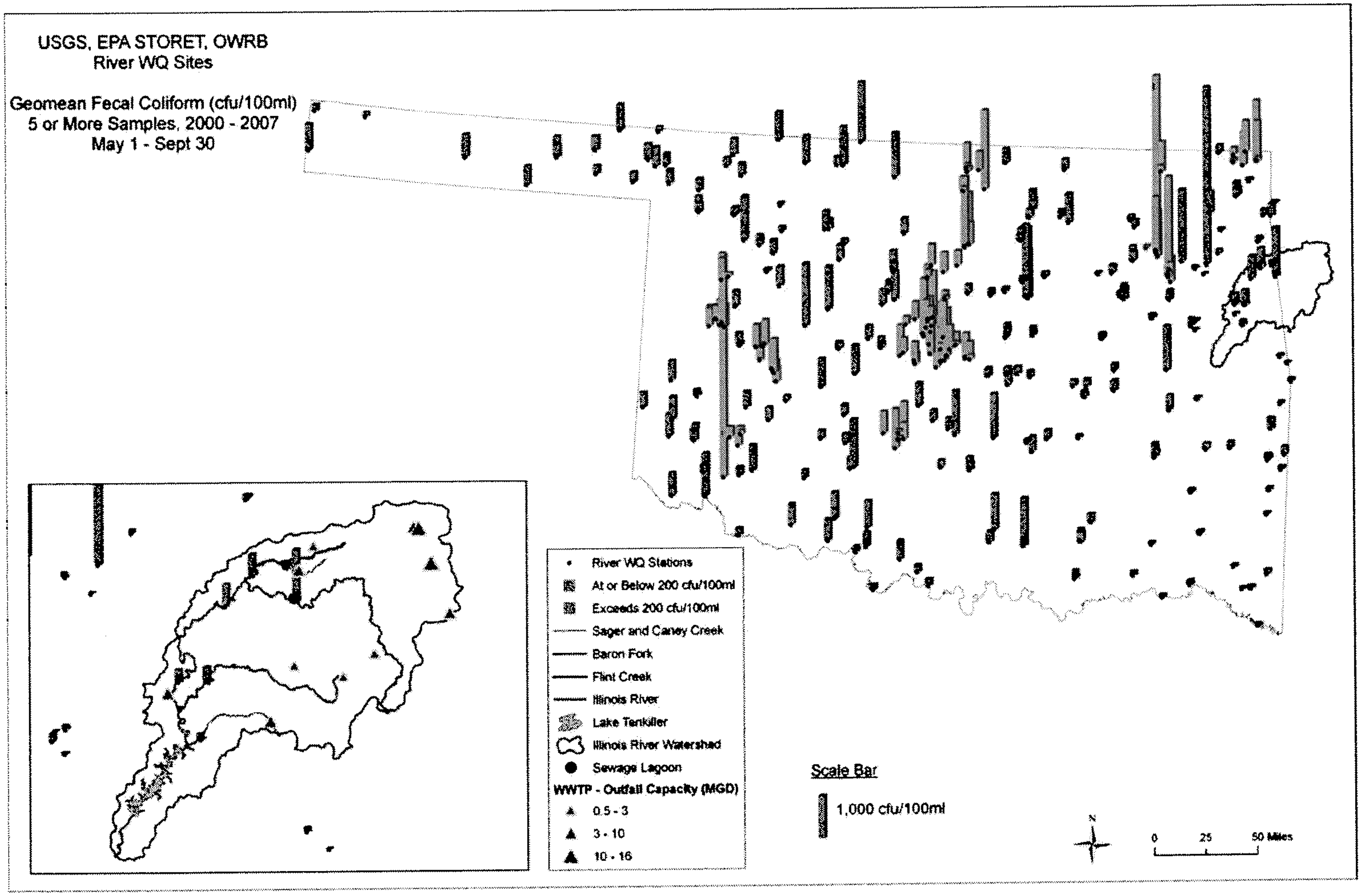

Figure 2-16. Map showing the geomean of fecal coliform bacteria concentrations measured at all sites in Oklahoma represented in USGS's, EPA's STORET, and OWRB's databases by five or more samples during the recreational period (May 1 to September 30) during the years 2000 through 2007. The height of each bar is proportional to the geomean bacteria concentration. Dots at the base of each bar show the locations of sample collection. The boundaries of the IRW are shown in eastern Oklahoma and northwestern Arkansas. Samples that exceed the primary contact geomean standard are shown in orange; those that do not exceed the standard are shown in green. The highest bar within the IRW is located directly adjacent to the sewage lagoon at Watts, OK.

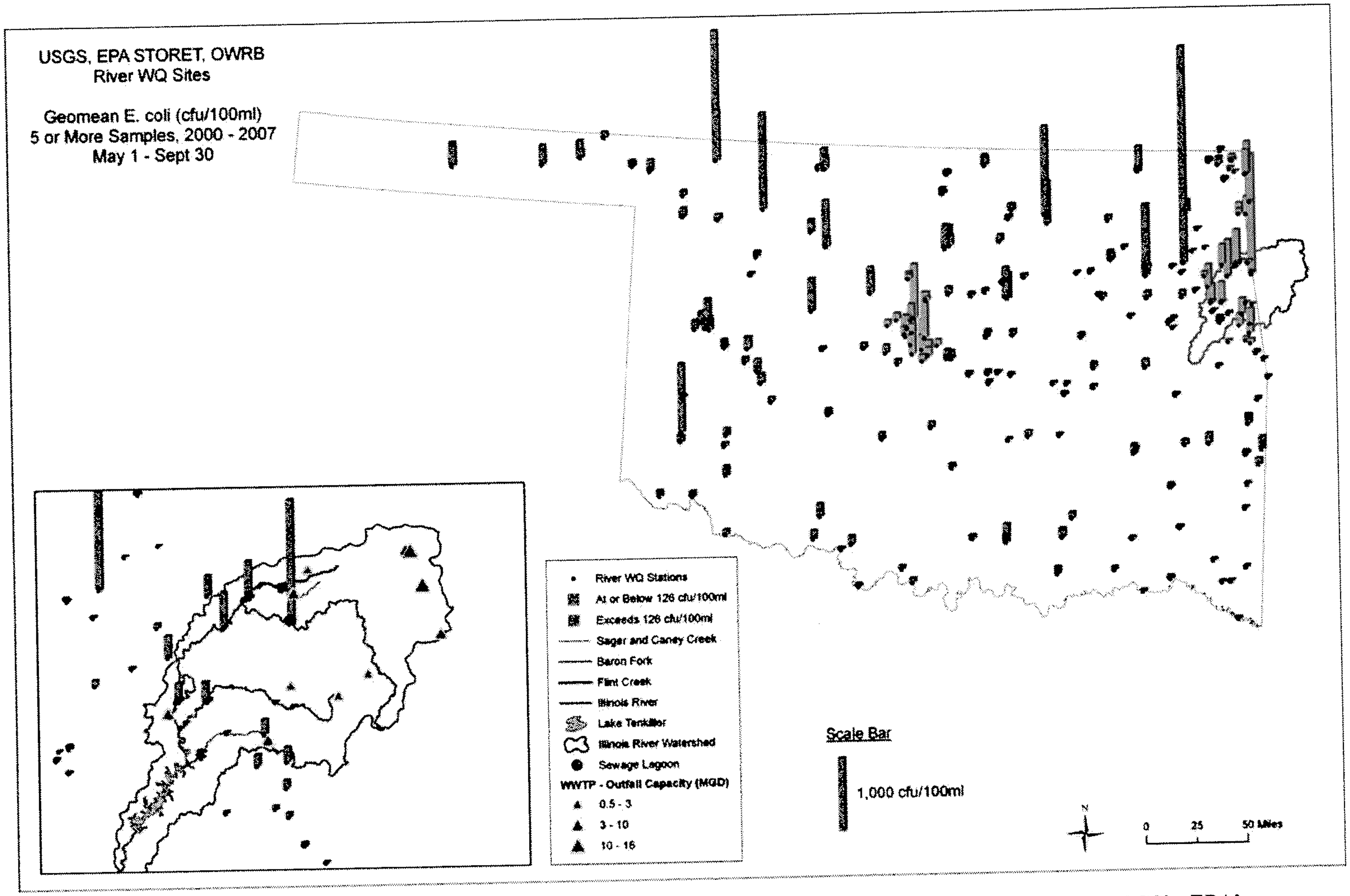

Figure 2-17. Map showing the geomean of *E. coli* concentrations measured at all sites in Oklahoma represented in USGS's, EPA's STORET, and ORWB's databases by five or more samples during the recreational period (May 1 to September 30) during the years 2000 through 2007. The height of each bar is proportional to the geomean bacteria concentration. Dots at the base of each bar show the locations of sample collection. The boundaries of the IRW are shown in eastern Oklahoma and northwestern Arkansas. Samples that exceed the primary contact geomean standard are shown in orange; those that do not exceed the standard are shown in green. The highest bar within the IRW is located directly adjacent to the sewage lagoon at Watts, OK.